AN INVESTIGATION INTO THE ADOPTION AND IMPLEMENTATION OF COMPUTER AIDED PRODUCTION MANAGEMENT SYSTEMS USING THE ROGERS MODEL OF ADOPTION AND IMPLEMENTATION AND A SOCIAL CONSTRUCTIONIST ACCOUNT 0F TECHNOLOGY

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SUMMARY

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An Investigation into the adoption and implementation of computer aided production management systems using the Rogers model of adoption and implementation and a social constructionist account of technology.

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The research investigates the processes of adoption and implementation, by organisations, of computer aided production management systems (CAPM). It is organised around two different theoretical perspectives. The first part is informed by the Rogers model of the diffusion, adoption and implementation of innovations, and the second part by a social constructionist approach to technology.

Rogers' work is critically evaluated and a model of adoption and implementation is distilled from it and applied to a set of empirical case studies. In light of the case study data, strengths and weaknesses of the model are identified. It is argued that the model is too rational and linear to provide an adequate explanation of adoption processes It is useful for understanding processes of implementation but requires further development. The model is not able to adequately encompass complex computer based technologies. However, the idea of 'reinvention' is identified as Rogers's key concept but it needs to be conceptually extended.

Both Rogers's model and definitions of CAPM found in the literature from production engineering tend to treat CAPM in objectivist terms. The problems with this view are addressed through a review of the literature on the sociology of technology, and it is argued that a social constructionist approach offers a more useful framework for understanding CAPM, its nature, adoption, implementation, and use. CAPM it is argued, must be understood in terms of the ways in which it is constituted in discourse, as part of a 'struggle for meaning' on the part of academics, professional engineers, suppliers, and users.

SCOT, Innovation, Computer Based Technology

To MaryB McGrath

and

Peter Clark

ACKNOWLEDGEMENTS

Case study data was collected whilst the author was a researcher on the ACME CAPM Project based at Aston University. The great bulk of the interviews were conducted personally but the author has also drawn on a number of interviews that were conducted by colleagues in the research team.

Chapter 3 is an extended version of the account of Rogers' ideas that appeared in Clark and Staunton 1989. However, this section of Clark and Staunton 1989 was written by me.

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CHAPTER 1

Introduction

This thesis is concerned with the processes of adoption and implementation, by organisations, of computer aided production management systems (CAPM). It is organised around two different theoretical perspectives. The first part is informed by the Rogers model of the diffusion, adoption and implementation of innovations, and the second part by a social constructionist approach to technology.

The interest in CAPM developed out of the research conducted at Aston University by the Innovation Design and Operations Management Research Group (IDOM) by whom I was employed as a researcher in the mid to late 1980's. This research was part of an SERC initiative which is indicative of the interest, at that time, in the application of computer based systems in manufacturing industry. A number of reports had indicated that the adoption of such systems was not widespread and, where firms did adopt, there was a high level of failure (NEDO, 1984; Ingersoll Engineers, 1985; Monniot et. al., 1987). The starting point for the research was, therefore, to examine the processes of organisational adoption and implementation in order to identify key problems and constraints.

Rogers (1962, 1971, 1976, 1983), over a long period, had developed a model of adoption and implementation that was both highly influential and also representative of many other linear type frameworks. The model provided a basis for structuring case study observation and analysis. By the same token empirical observation would permit an appraisal of Rogers model as an analytical tool in the investigation of adoption and implementation processes.

However, during the course of gathering empirical data through case studies two things became clear. First that, although the Rogers model does provide a useful framework for understanding implementation as a flexible and iterative process, it's treatment of the adoption process is too simplistic and can be characterised as a model of rational decision making akin to that of neo-classical theory and anchored in the equally rationalistic communication theory perspective.

The second thing to emerge from the case study observation and review of literature was that CAPM itself became a highly problematic concept and, in my eyes, underwent something of an identity crisis as it became increasingly difficult to pin down just what it was I was observing and analysing. This was compounded by the difficulties that arose in attempting to assess the relative success or failure of implementations. This issue became greatly important to the way in which CAPM systems are conceptualised from different standpoints. The way in which this issue is treated in the engineering literature is highly functional and technical approaches, in my view, do not do justice to the complexity of the social processes that surround such judgements. I found that definitions and descriptions from production engineering, which were my starting point, did not adequately conceptualise the nature of this complex 'technology' and, in consequence, I turned to the then emerging literature on the social construction of technology to try to develop a fuller understanding.

As a result of these problems I have attempted to present an account of CAPM that is very different from the one I started with; one which sees CAPM as a social construction better understood in terms of the discourses that underpin it, and the struggle by users to give meaning to it, than in the technical specifications of hardware and software. The implications of this for the research problem I began with are important. In one sense I am suggesting that CAPM systems do not really exist; the name CAPM appears to a have virtually vanished from usage. Yes, computer based systems are adopted by organisations and computers are used in production and many other areas of manufacturing industry. But to identify a system as 'CAPM' and to describe it in purely technical terms does not do justice to the 'interpretive flexibility' of the technology. Neither does it do justice to the way in which the nature and identity of CAPM is something that is negotiated in particular contexts and is structured by the interests and ideologies of various parties, professional engineers, suppliers, users, academics and government agencies. I will argue that not only is the form and content of CAPM malleable and negotiated in specific contexts but that its purpose too is equally indeterminate.

The way in which my ideas were evolving over the period of conducting the research and review is reflected in the organisation of the thesis. Chapter two outlines methodological issues. Chapter three presents a critical, analytical account of the Rogers framework and distils from it a model to be applied to the case studies of CAPM adoption and implementation. Chapter four provides the account of CAPM culled from the production engineering literature prior to case study data gathering. Chapter five attempts to apply both the Rogers model and the conceptualisation of CAPM to particular instances of adoption and implementation by different organisations.

Chapter six reviews the case studies and examines both the Rogers framework, and the emerging problematic nature of CAPM. The result of this is that, in my view, Rogers' account of adoption is undermined but his account of implementation provides a fertile basis for understanding organisational processes, but it is not able to account for the nature of complex computer based systems and it is necessary to go beyond his framework to find a theoretical approach in which to locate CAPM. Rogers notion of reinvention is very important but his conceptualisation is restricted and needs to be developed to include the purpose of the innovation as well as form and content.

Chapter seven moves on to a much broader review of literature and discussion of the nature of 'technology' and tries to identify the tradition in which Rogers is located and indicate more fertile directions. Consequently an account of technology as a social construction is presented. In chapter eight I return to CAPM in order to apply the new social constructionist framework to it, and to identify both strength and weaknesses in this approach. I will argue that, despite some limitations, this approach provides a basis for a richer understanding of processes around the adoption and implementation of CAPM systems.

CHAPTER 2

Methodology

This thesis is centrally concerned with two main things: the process of innovation in organisations and the nature of computer based technologies. Both of these have been the focus of a great deal of research activities and a number of different methodological approaches have been adopted by different researchers at different times. As noted above as the research progressed so the nature of the particular innovation (CAPM) became highly problematic and this entailed a methodological departure from, or an extension to, the original research design.

The approach I have adopted has three elements to it. First I have reviewed the work on innovation of Everett Rogers in order to distil from that a framework for exploring the process of innovation in organisations. I have then applied this framework to a set of case studies in the adoption and implementation of an innovation, CAPM (Computer Aided Production Management) systems. Following on from this I have returned to the Rogers framework to identify strengths and weaknesses. As a direct result of this I have identified a key weakness in Rogers' framework's ability to conceptualise complex computer based systems and this has necessitated the incorporation of a broad literature including both professional and academic concerns in order to produce a fuller understanding of the technology in question. This represented a methodological shift from case study to discourse analysis.

This shift, and the organisation of the thesis reflects the developmental nature of the research. The starting point was concerned with identifying the reasons for the widespread failure of system implementation, and the

Rogers model offered a useful methodological device to this end. However, as the research progressed, on a part-time basis, over an eight year period, the starting points themselves became the subject of re-evaluation and other perspectives were incorporated in order to address the emerging problems: particularly concerning the nature of the technology. I would argue that this response was necessary to do justice to the conceptual issues as they emerged, but it does mean that the collection of the empirical data was informed by a different understanding of the technology to that which informed its later analysis. This clearly raises issues of methodological consistency but I would also argue that Rogers concept of 'reinvention' which will be the subject of much discussion later, represents a theoretical and conceptual bridge that provides an important point of contact between the different literatures.

Understanding Innovation as a Process.

The commitment to a particular methodological approach springs from a prior commitment concerning the stance the researcher takes on two underlying questions: what is the nature of the subject to be researched?; and what is the most appropriate way to gain adequate knowledge of this? From this specific research strategies can be formulated and specific methods adopted. Bryman (1988) treats methodological positions as falling into one of two traditions which can roughly be characterised as qualitative/interpretive or quantitative/explanatory. This is not intended as a definitive taxonomy but as a useful heuristic device. The approach I have adopted falls into the qualitative research and, in particular, I have adopted a processual approach as opposed to a variance approach. The reasons for this are as follows.

In an important article in 1976 Downs and Mohr drew attention to the problem of observed instability in empirical findings which seemed to suggest that methodological approaches to organisational innovation were seriously flawed. One major reason for this, they suggest, is that much research design is informed by a commitment to a variance mode of explanation. Indeed, a great deal of organisational research has tended to adopt this kind of positivistic approach (Bryman, 1988, 1989) which shares similar epistemological canons to those of the natural sciences. This approach is often concerned with the testing of theory based hypotheses against observed empirical regularities and is characterised by commitment to objective measurement, identification of causal links between clearly operationalised variables, usually with a view to producing generalisation. In innovation theory the aim has often been to identify those key variables that are correlated with innovative activity.

The requirement for measurement is satisfied through the development of variables from operational definitions of concepts, but a key problem with the process of operationalisation is that there is always a serious danger of corrupting the concept during the operational procedure (de Vaus, 1990). For example, in the case of organisational studies common variables might be size, turnover (e.g. Benson et. al., 1987) or centralisation (e.g. Moch and Morse, 1977), however instabilities can arise as a direct result of operational decisions, at both a conceptual level (e.g. how is size conceptualised in a large decentralised organisation?) and at an empirical level (e.g. how, for example, is size understood: as turnover, or number of employees etc.?) (Hopkins, 1988). Clearly decisions made at this stage in research design will have important implications for eventual findings.

The production of operational dimensions is directly related to a commitment to a particular kind of causal explanation rooted in variance analysis (Mohr, 1982) in which any variance in one variable, e.g. 'innovativeness', is explained in terms of the variance in another or groups of others, e.g. 'cosmopolitanness' (Rogers 1962, 1972, 1983).

Mohr (1982) has outlined some of the problems associated with variance theorising and made a strong case for a need to shift to a processual approach. This differs from the variance approach in a number of ways. In variance theory explanation is constructed in terms of causality conceptualised in terms of necessity and sufficiency (efficient causality): the precursor is seen to be a necessary and a sufficient condition for the outcome. Process theory, on the other hand, is less prescriptive and constructs explanation in terms of probabilistic realignment and necessity but not sufficiency. In this case the precursor is necessary for the outcome but not sufficient. Variance theory deals with variables whereas process theory deals with discrete states and events. In variance theory time ordering among the contributing (independent) variables is immaterial to the outcome, but in process theory time ordering among the contributing events is generally critical for the outcome.

Mohr uses the example of malarial infection to demonstrate a fundamental weakness of variance research which is that it tends to take for granted the very thing that needs explaining. In this case the observed instability in the findings of innovation theory can be explained in terms of the imposition of an inappropriate explanatory framework. For example, the fact that organisational size can be correlated with both innovative and non-innovative behaviour (Bryman, 1989; Mohr, 1982) is explained in terms of the (hidden in variance theory) processes that link events and entities. So in the case of the contracting of malaria what is important is, not the variance in mosquito or human populations, but the complex process by which they are combined to produce a particular outcome. But because this is a process that depends upon the combination of a sequence of events and conditions the outcome is never assured: a mosquito may or may not bite a human being, and a mosquito bite may or may not lead to the contraction of malaria. Of course it can be argued that variance in mosquito population can be positively correlated with an increase in the rate of malarial contraction. This may be so, but it is meaningless in itself because an adequate explanation must include the processes that make this association possible. To contract malaria it is necessary to be in an environment where the mosquito can survive, to be bitten by a particular kind (Anopheles) of mosquito that has bitten a human carrying the malarial parasite, *in that order*. Events, conditions and sequence are all essential to the outcome of the process. To shift the analogy back to organisational innovation, organisational size can only be a relevant factor in explaining innovation in the context of other conditions, events and sequences: there is absolutely no reason to believe that varying the 'size' of an organisation will lead to increased innovation. Thus to understand innovation it is necessary to understand processes and not just amounts.

Mohr then, has produced a view of process theory that is committed to causal (if probabilistic) explanation and thus remains committed to an explanatory framework, and Rogers (1962, 1972, 1983), despite maintaining vestiges of variance theory, provides a highly influential example of the application of such a theoretical approach to the study of organisational innovation. This provides a very useful vehicle for case study analysis in trying to identify processual elements in adoption and implementation outcomes. However, as will become clear, in the case studies discussion this particular approach to process theory has some weaknesses.

Why use Rogers framework at all if, from the outset, it is clear that it has limitations? Rogers model can act as a kind of focusing device and a major point of interest will be to explore the degree to which this model is a description of actual organisational processes or a methodological device useful for the collection and organisation of empirical data. For Rogers the former is clearly the case, however in my view the latter is a more helpful way of thinking about it.

The relationship between the framework and the data is a mutual one: the framework provides a useful rationale for collecting and analysing data and for observing processes of organisational innovation and, at the same time, provides an opportunity to explore strengths and weaknesses of the model in a critical way. The idea of critique as method has a long history (Barblet, 1978). Karl Marx, for instance, used it consistently in both early and late periods to engage with, in his early work Hegel, and in his later work classical political economy. In *The Critique of Hegel's Philosophy of Right* he proceeded by a paragraph by paragraph critique of Hegel in an attempt to 'extract the rational kernel' from Hegel's work (Sayer, 1979), and in a sense this is what I am attempting to do with Rogers. In this instance the engagement with Rogers' framework and case study data leads to a return to methodological/epistemological issues later as both the strengths and the shortcomings of Rogers' approach are identified, particularly in relation to his treatment of innovations and the nature of technical artifacts. In order to explore these issues it is necessary to move beyond process as an explanatory framework to one in which process is conceptualised as an interpretive (Denzin and Lincoln, 1994) and even constitutive activity (Woolgar, 1991). These issues will be dealt with in depth later.

Research Design

The commitment to a processual account of technical innovation led me to adopt a case study approach. This approach has a long pedigree in organisational research but often the rationale for it is very different between researchers (Bryman, 1989; Stake, 1994) ranging from generating ungeneralisable 'thick description', to theory testing. In relation to this research the case study has a number of advantages and in particular it facilitates the reconstruction of the process of innovation adoption as it was experienced by those involved in it.

The Case Studies

Four companies from the components sector were selected as main case studies and two other companies from the foundry sector as smaller cases. ElectroCo Engine Management Systems in the auto-components sector, FoundryCo and BritCo Precision from the Foundry Sector and PlasticCo from the Plastic Moulding sector. The intention was to select companies to represent diverse facets of the adoption/implementation process in terms history of involvement with computer systems, type of business, and of CAPM system. Given the commitment to a process approach that emphasises context it was essential to observe the innovation in a number of different settings. The final choice was not, of course, a free one and problems of access also play an important part in the final selection. For example a number of other companies refused to participate in the research and still others proved inappropriate following initial interviews as too many restrictions were placed on the researcher's remit. Further, in the case of FoundryCo, one of the foundry cases in the study, although good access was secured to the central facility and two operating companies, access to a third operating company, that was actually in the process of implementing a system, was not granted. Despite these limitations the final cases did provide the possibility observe the 'innovation process' in a variety of different contexts.

The companies had varying degrees of experience with computer systems and in-house expertise. PlasticCo and BritCo Precision were both implementing their first system, whereas FoundryCo had developed their own mainframe system over a long period of time. ElectroCo Engine Management Systems were part of the ElectroCo Industries Group and had a great deal of experience in the use and implementation of computer systems. The smaller foundry companies had very little previous experience of computers.

The companies represented organisations at various stages in the adoption and implementation process. PlasticCo were in the actual process of implementation, ElectroCo and BritCo had recently 'completed' the process, FoundryCo was in the process of expanding and developing an existing system and the two smaller foundries were at the early stages of adoption and implementation.

The scale, complexity and level of integration of the various systems also varied greatly and these will be described later.

Three of the cases were operating companies in a larger corporate organisation. FoundryCo was a centrally driven system and so interviews were conducted both at the centre and in two of the operating companies.

Data Collection.

Data was gathered by means of in-depth interviews with key personnel. Contact was initially established with a senior person in the organisation and other informants were identified through a process of snow ball sampling (May, 1993) in which after an initial interview informants were asked to indicate other possible informants who were involved or would have knowledge of particular events or episodes. In this way other key personnel were identified and interviews arranged and conducted.

The aim of the interviews was to attempt to reconstruct the adoption and implementation process by identifying key moments, issues and outcomes. In each organisation, where possible, staff from every department concerned were interviewed so that an overview could be established. This also made it possible to verify accounts and to identify various organisational tensions. The interviews, themselves, were semi-structured: the Rogers framework provided an ideal type staged sequence of change from antecedents through adoption, implementation and routinisation. (This will be discussed in detail later) and each informant was probed for information on each stage or state. However it is imperative to note that the intention was not to impose this framework on each situation but rather to use it as a device to focus informants on the issues of interest. At the same time questions were often very open-ended in an to attempt avoid the framework becoming a straight-jacket. 'Rambling' (Bryman, 1988; May, 1993) was encouraged to enable informants to raise issues of importance to them and so clarification and elaboration was encouraged.

Conducting interviews can raise a whole series of epistemological and practical problems for the researcher. Epistemological issues raised concern how to assess the 'validity' of accounts: that is, are the accounts reliable, objective reconstructions of the process under investigation or biased, subjective distortions? Different researchers hold different views on this from those who take great pains to remove 'bias' (e.g. Monniot et. al., 1987), to those who dismiss the search for objectivity as a mistaken venture in the first place as all social interaction is considered textual and constitutive. (e.g. Atkinson, 1990; Woolgar, 1991).

Questions of reliability and validity are more appropriate to quantitative, variance research but there still remains the question of status of interview accounts. There are two issues here: the first concerns the way in which the research design may impact upon informants (Bulmer, 1984); and the second concerns problems of veracity. Many interviews involved the post hoc reconstruction of events and actors tend to produce rationalised accounts of processes that are, in reality, much messier. This problem is compounded by the use of the Rogers' model as it provides a ready made rationalisation of complex processes. As far as possible I endeavoured to check accounts for consistency between informants and this sometimes necessitated return visits. On the other hand, it became clear as the research progressed that the analysis of data could not be confined to attempting to build accurate or objective reconstructions of processes as it was clear that the discourses (Atkinson, 1990) surrounding computer based systems (Kling, 1992) were themselves an important resource in 'making sense' of the data, and this will be the focus of a later chapter.

Processual accounts of interaction, like Mohr's (and Rogers') also run into difficulty as there is an attempt to establish causality and this relies on achieving a high level of veracity. A problem is, however, that a great deal of the substance of social interaction is not amenable to direct observation (Atkinson, 1990) and this is particularly true in the case of computer based systems (Kling, 1991). We can try to observe them through their effects, but even this is problematic as Woolgar (1991, 1992), for example argues that technological artifacts can have no effects and can only be understood interpretively through the accounts provided by the actors.

In practical terms interviews of this kind which are face to face, thus lacking the anonymity of a questionnaire, and which often entail exploring sensitive issues or performance and politics require sensitive handling. For example, mode of access and perception of researcher can affect the way in which respondents perceive the researcher. As a sociologist entering the world of manufacturing industry I was concerned to limit the sense of difference between researcher and researched as far as possible without misleading informants in any way. For example, prior to beginning the case studies I spent a great deal of time studying standard production engineering texts in order to build up a familiarity with concepts, techniques and language. At the beginning of all interviews I stressed the independence of the study and the confidentiality of the data. Most informants agreed to the interviews being taped but I also urged informants to ask for the tape to be switched off at any stage of the interview if they were at all concerned about confidentiality. This occurred on two occasions.

As the research continued and unanticipated issues arose a number of key individuals were interviewed on two or more occasions so that the issues could be explored further. Most of the field work was conducted in a nine month period between July 1987 and April 1988. In the case of PlasticCo, because the implementation was actually taking place, interviews were conducted at intervals over a twenty month period so that the actual course of the implementation could be followed. All the interviews were tape recorded and transcribed.

Understanding CAPM

As the case studies progressed, and particularly whilst analysing the data, I became increasingly uneasy about the nature and status of CAPM and found it more and more difficult to separate CAPM from the context in which it was embedded. It was also difficult to distinguish the 'system' from 'talk' about the system. For example, this was particularly acute in the case of actors assessments of success and failure. Even of those companies who would be considered to have failed, in one way or another according to the accounts outlined by production engineers (I will explore this later), *did not see* their system as a failure, and quantification was problematic for a variety of reasons. Actors were acutely aware that some highly important outcomes were unquantifiable, like the benefits that spring from organisational changes accompanying computer implementation. Even the company in which the computer system was abandoned still managed to achieve the objectives that the computer system had been intended to achieve. The problems around assessments of success vs failure led to a re-evaluation of the nature of the technology in terms of the discourses surrounding it and the 'struggle for meaning' of the actors concerned.

This is not simply a question of bias or bias avoidance as actors 'talk' or 'discourse' (Gilbert and Mulkay, 1984) is indicative, not necessarily of some independently existing entity, but of the interpretations and understandings of the actors in which computer based technologies are socially constructed. Kling (1991a) has argued that the 'computer system' is a convenient fiction that deletes the nuances of organisational processes through talk of the computer, and Woolgar and Grint (1991) see this as a point of key importance that concerns more than the ways in which technologies are labelled; it concerns the ways in which the nature and capacity of a technology arises in and through the discourse of which it is a part. Thus understanding of social action is concerned with the interpretation of social action as well as with its causal explanation (Bulmer, 1984).

The use of qualitative method necessarily requires an openness and a flexibility on the part of the researcher to evaluate and re-evaluate initial assumptions in the light of evidence from the field. Often such an approach tends to be atheoretical and non-evaluative, aimed at producing 'thick description' of intrinsic as opposed to general interest (Stake, 1994). Secondly, at the same time by applying the Rogers framework in a critical manner it provides a basis for instrumental interest (Stake, 1994) aimed at the interrogation of a theoretical model, in this case Rogers'. It also entails a willingness to relinquish previously held ideas and respond to the emerging picture. In the course of this study a major development was that in working through the various accounts of the process it became clear that the concept of 'CAPM' as a starting point was greatly problematised and led to a substantial re-evaluation of its nature and status and its place in organisational contexts.

The problematisation of CAPM made it imperative to go beyond the case studies to examine the discourses surrounding its development and diffusion. Here social constructionist accounts of technology provided useful concepts for exploration not available through Rogers. To pursue this further I undertook an extensive review of the professional literature on 'CAPM' to chart the ways in which discourses, in which it is anchored, have developed. In particular I examined changing accounts of 'CAPM' in the APICS journal over a period from the late 1970's to the early 1980's. The aim here was to show how CAPM is a social rather than technical construction and to apply the concepts of social construction, particularly 'controversy' and 'interpretive flexibility' to CAPM. This will be discussed in depth later.

CHAPTER 3

The Rogers Perspective

Everett Rogers has been enormously influential in the fields of innovation and innovation diffusion, indeed he has been referred to by one writer as the 'doyen' of innovation theory (Brown, 1981). Despite a number of significant developments and reassessments over a period of twenty years between 1962 and 1983 a clear line of continuity of both theoretical and conceptual development can be identified in his work. The third edition of the "Diffusion of Innovations" was published in 1983. This development will be outlined below and supplemented by a discussion of the richer contribution made by Rogers and Shoemaker (1971) and the 1976 work "Communication in Organisations" (Rogers and Rogers).

In order to understand Rogers ideas it is important to locate them in the particular historical context in which they developed and in the intellectual traditions in which they were formulated. Firstly, the contextual influence on his early work, which serves as a foundation for the later, is grounded in the activities of the American agricultural agencies during the 1950's aimed at the promotion of best practice amongst farmers particularly with reference to the spread of innovations including hybrid seed corn and agricultural equipment and practices. Thus a supply side emphasis is clear in the approach: Rogers sets out to identify and disseminate the appropriate methods to be employed by central agencies to secure the efficient diffusion of particular ideas, equipment and practices within targeted communities. Secondly, Rogers formulation of the diffusion process is anchored in the theoretical seas of communication theory and rural sociology. This tradition, takes a highly rationalistic perspective and the diffusion process is conceptualised as the spread of a new idea from the source of invention or creation, through various channels of information, to its ultimate users or adopters. In my view the evolution of Rogers framework can be understood in terms of tension between the recognised shortcomings which stem from the former influence and the attempt at theoretical development which is constrained by the latter.

The formulation which Rogers articulates in the 1962 edition is largely consistent throughout his work although it has undergone a number of revisions. The general framework for analysis is underpinned by the following understanding: *an innovation is something that is perceived as new by an individual and which is communicated from one individual to another in a social system over time.* (e.g. 1983:35)

Although I have argued that Rogers develops a supply side model his work is perhaps best seen as a model of adoption. Adoption is the central focus of attention and the key to the diffusion process. Given that in communication theory the process of innovation diffusion is conceptualised in terms of the communication of information the concern is primarily with factors which facilitate its effective flow (Williams and Gibson, 1990). Thus information reception and resistance are crucial characteristics. It is the point at which individuals within a social system take the decision to adopt, and the identification of the various influences that affect that decision which is the central concern of Rogers theoretical perspective. There are two essential components to this: firstly the individual's propensity to adopt, which Rogers refers to as his/her level of "innovativeness", and secondly the congruence between this and the perceived characteristics of the innovation.

Innovativeness is defined, somewhat tautologically, as the degree to which an individual is relatively earlier in adopting new ideas than other members of the social system. Innovativeness is the concept on which Rogers model turns: it is central to both an explanation of the level and rate of the diffusion of innovations. It is also a very problematic concept to which I will return later.

The concept of "innovativeness" is used to produce a taxonomy of adopter categories. These are innovators, early adopters, early majority, late majority and laggards. These categories are presented as ideal types and their presence in a given community conforms to the normal distribution bell shaped curve. These adopter ideal types are then ascribed a corresponding set of dominant characteristics: venturesome, respectful, deliberate, sceptical, traditional. A linear scale running from innovators to laggards is then devised to produce adopter types. In this scheme it is held that innovators are more likely to be of high social status and laggards of low social status. Innovators are more likely to be younger, better off, more cosmopolitan, are likely to use more information sources, utilise more specialised operation, be of higher intelligence and greater opinion leadership. Innovators are characterised as social deviants who are "...in step with another [presumably more cosmopolitan] drum" (1962: 207) who identify with different reference groups outside of the community. The overall schema remains intact although later versions are more extended and differentiated (e.g. 1983: 260)

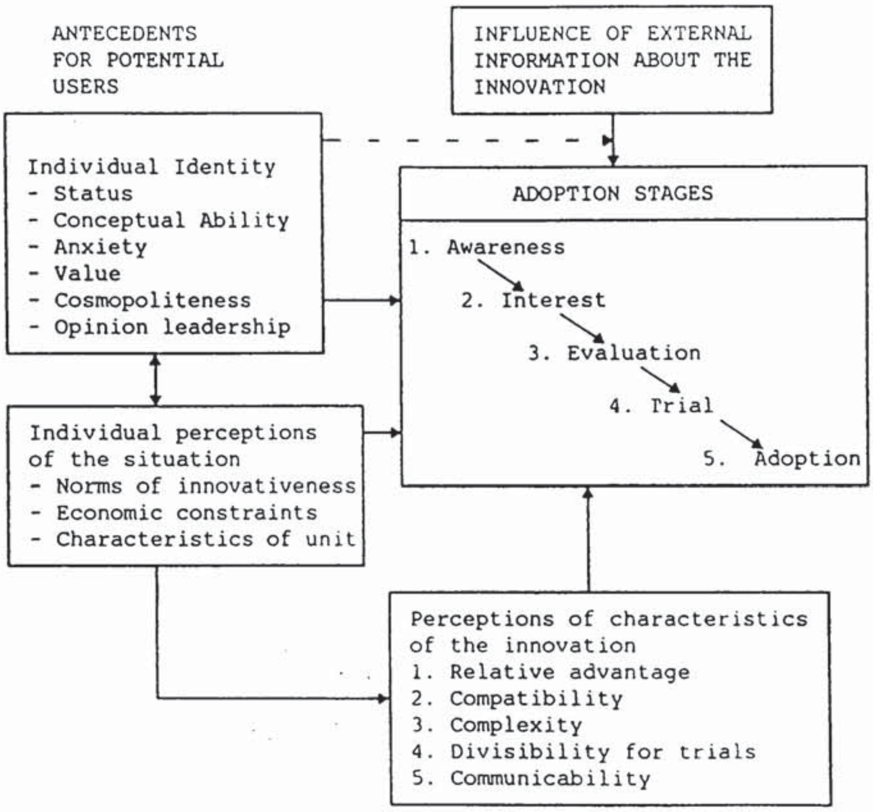
Specifically then, Rogers is concerned with varying levels of innovativeness within aggregate populations which he seeks to explain in terms of the socio-psychological characteristics of individuals. His aim is to establish the relationship between these levels and the degree and rate of the diffusion of innovations.

The adoption process itself is conceptualised as a mental process through which an individual passes from first hearing of an innovation to final adoption. This process has five stages or steps. In the early model the stages are *awareness* which refers to initial exposure to an innovation during which time information is limited. The *interest* stage involves the individual in a quest for further information. This is followed by a period of *evaluation* in which the individual makes a mental assessment of the costs and benefits of the innovation. This leads to a small scale *trial* before final full scale *adoption*. During this process the type of information to which an individual is exposed is crucial. At the early stages impersonal information is important whilst during the later stages personal information becomes more important.

Figure 1 illustrates the features of Rogers early model. It can be seen that there are three major aspects: the *antecedent context* of potential innovators, the *characteristics of the innovation*, the *innovation process*.

It should be noted that at this point Rogers understanding of antecedent conditions is conceptualised in tightly bounded terms corresponding to individual psychology and the socio-psychological parochialism of community: that is antecedent refers to the culturally embedded predisposition of potential adopters. External influences are restricted to the flow of information about the innovation via media channels. The diffusion of a particular innovation amongst a given population is, therefore, explained in terms of the interplay between information flow and the intrinsic characteristics of communities and individuals.

Figure 1: Rogers' Early Model



Source: Clark and Staunton 1989

If the level of diffusion is a function of the characteristics of individuals and communities vis-a-vis levels of innovativeness, the differential rate of diffusion between different innovations, on the other hand, is explained in terms of the characteristics of the innovations themselves. Rogers produces a list of characteristics by which any innovation may be described and which are of predictive value (for the field agents of the agricultural extension agencies). The five characteristics of innovations are: *relative advantage*, *compatibility*, *complexity*, *divisibility*, and *communicability*. Relative advantage refers to the degree of superiority of the innovation to that which preceded it. Relative advantage may be emphasised by crisis which may either accelerate or retard the rate of adoption. Profitability is an important element in this. Compatibility refers to the degree an innovation is consistent with the values and past experiences of adopters. Complexity refers to the degree to which an innovation may be understood by potential adopters. Divisibility to the degree to which it may be tried on a limited basis and communicability to the degree to which the results of an innovation may be diffused to others. Rogers is a little vague as to whether these characteristics can be seen as objective attributes of innovations but he is clear that what is most important to the adoption decision is the way in which potential adopters perceive the characteristics of an innovation.

Rogers recognises that cultural values are an important determinant of the diffusion/adoption patterns but he is inconsistent over the precise role. There are clear overtones in his account of the early writers in the modernisation school of development theory who conceptualised the problems of Third World countries in terms of their backwardness on a universal scale of societal characteristics. For example Hoselitz (1960) attempted to apply Talcott Parson's 'pattern variables' to the problems of development and underdevelopment[1] in which the process of 'modernisation' was conceptualised in terms of a backward community taking on the characteristics of an advanced (modern) one. In language reminiscent of Rostow's (1960) Rogers uses the rather simplistic, ideal type, dichotomy of "traditional" and "modern" as a simple determinant of a communities propensity to innovate. In the later model although a similar dichotomy is used it is now presented as a reflection of 'aggregate inclination'. Nevertheless this dichotomy, and its roots in modernisation theory, remains an important element in his framework.

The rate of adoption is a function of the influence of adopters on non-adopters in a social system which leads to the internalisation of relative advantage. Opinion leadership is an important concept for Rogers. Opinion leaders are those individuals from whom others seek advice and information they are significant individuals in the community who by example exert influence on the behaviour of others. They are important elements in the flow of information. This information flow is characterised simply by Rogers in terms of two steps from media to opinion leaders to the community at large. The personal influence of the opinion leaders is especially important at the evaluation stage, for relatively late adopters and in uncertain situations.

Rogers also ascribes an important role to the "change agent" whom he describes as a professional person who seeks to influence adoption decision. They are rarely perceived as credible by their clients who feel they tend to foster the overadoption of new ideas and so the role of the change agent (in this case the agricultural agencies) is the identification of

1 For a discussion and critique of modernisation theory see for example Bagghi, A.K. (1982), Blomstrom, M. & Hettne, B. (1984) & Alavi, H. & Shanin, T. (Eds) 1982.

such individuals (opinion leaders) in order to produce a catalytic effect and generate or accelerate the diffusion process.

The rationale for the model is clear. It is intended as an instrument of planning and execution for the use, in this instance, of the agricultural extension agencies in the organised attempt to promote and diffuse their definitions of best practice among farmers. The model has been enormously influential in the United States in terms of the implementation of both internal and overseas development policy.

The original model has undergone a number of extensions, refinements and revisions (Rogers and Shoemaker, 1971; Rogers and Rogers, 1976; Rogers, 1983). The work is extended to incorporate a discussion of the generation of innovations and also the consequences of innovation. However, three important developments stand out: firstly the attempt to address the question of innovation in organisations which necessarily involves a shift away from a focus on individuals; secondly the recognition that in the process of adoption innovations are also adapted in the context of specific applications, this Rogers refers to as "reinvention"; and thirdly an awareness of the 'pro-innovation bias' of the earlier model.

Rogers and Shoemaker (1971) show an awareness of the limitations of diffusion research (including Rogers own earlier model). In particular they note the shortcomings of approaches which focus on individual decision making processes as opposed to organisational decision making processes. As a corollary they are critical of approaches which take the individual as the unit of analysis and argue for a need to focus upon social relations. The overarching approach is still one which is centrally concerned with information flows but now there is an awareness that such flows cannot be understood as in the earlier communication model and must take account, for example, of the "sociometric diad" or inter personal networks which are obscured by the methodological procedure which draws on random samples of individuals. This has the effect of obscuring influential social networks and tends to lead to a poor "aggregate psychology" (1971: 80). It is pointed out that it has erroneously been assumed that because individuals were the units of response that individuals were also the units of analysis.

The conceptual framework remains pretty much intact but there are a number of elaborations concerning points of detail. The concept of the "performance gap" is now incorporated into the category of antecedent conditions (This concept is developed further in Rogers and Rogers 1976 and I will return to this later). The decision process itself is modified and now consists of four stages: *knowledge* which is similar to the earlier awareness stage; *persuasion* which is similar to the earlier *interest* stage; *decision* which replaces evaluation and adoption; an important development is the inclusion of an *implementation* stage; *confirmation* which refers to attempts to reduce 'innovation dissonance'. The earlier trial stage has been dropped.

Innovation attributes are also slightly modified. Divisibility is referred to as "trialability" in order to include the notion of a psychological trial. "Communicability" is modified to "observability" and it is now clear that the characteristics of innovations refers to perceived characteristics.

An important development in later works is the notion of "innovation bundles" (1971) or "technology clusters" (1983). By this Rogers is referring to the problems associated with a concentration on single innovations. Favourable perception of innovations is in part a function of compatibility, and this in turn is related to innovations which have already been adopted. Thus further innovation will be dependent upon other innovations which potential adopters are using. There is a need therefore to study "bundles" or "packages" of innovations rather than each innovation as discreet and separate unit of analysis. To some extent this tacitly anticipates, albeit in an underdeveloped way, Gille's (1986) notion of the "technical system".

Discussion

Rogers exposition of the diffusion adoption process, in his early works, provides an important improvement on variance approaches but is nevertheless open to a number of criticisms: some concerning points of detail but others, more seriously, which concern important omissions and conceptual limitations.

Firstly, Rogers classifications of psychological types appears arbitrary and he appears to offer little substantial evidence of their actual existence. In part this is a result of methodological weakness which is characterised by tautological assumptions. Thus Rogers begins his analysis from the empirical observation that adoption rates follow a normal distribution pattern: adopter distributions tend to follow a bell shaped curve over time and approach normality (1962: 158; Ryan and Gross, 1943; Grilliches, 1957; Mansfield, 1961). From this observation of empirical regularity Rogers develops his categories of adopters ranging from innovators to laggards. This classification is based on ascribed levels of "innovativeness". But Rogers definition of "innovativeness" is ambiguous; on the one hand it refers to

> "..the degree to which an individual is relatively earlier to adopt new ideas than other members of his social system."
>
> (1962:159)

Thus it is a classification of observed behaviour. On the other hand, in language very reminiscent of variance research, it is also an intrinsic quality which is possessed to a greater or lesser degree by various individuals

> "One has either more or less innovativeness than others in a social system."
>
> (1962: 160)

Thus "innovativeness" is both cause and effect: the incidence of empirical regularity is used to explain it-self. In his discussion of the dimension of his ideal type categories of "innovativeness" Rogers is sparse with his presentation of evidence. The same is true of the "personal characteristics" classifications: Rogers admits that " there is not unanimous support for this generalisation" (age: 172) and evidence is "fragmentary" (Mental ability: 177). Variables like "wealth" are reduced to dimensions of behaviour (175).

The problems which are raised by the concept of "innovativeness" are many. The problem springs from a limitation of scope and in turn creates further limitations of scope. In particular Rogers preoccupation with this concept is a product of limited concern with what Grilliches (1957) has termed the acceptance problem at the expense of the problem of *availability.*

Underpinning Rogers model is understanding that innovations spread through time and space as part of a process of information dissemination.

The spread of information is seen to be even, comprehensive and innovation is always the best course of action, thus the focus of analysis is point of adoption and in particular on barriers to reception and acceptance. This is why an individual's proclivity to innovate, their "innovativeness" occupies a conceptual ascendancy and why "opinion leadership is an important concept. The questions which Rogers addresses, to the exclusion of others, are what particular personal qualities and what social attributes produce higher levels of innovativeness in some individuals as opposed to others? This is the acceptance question.

What this approach puts out of bounds is what Grilliches (1957) and Brown (1981) call the availability question. This refers to the activities of supply side agencies which exert pressure on the process of information and innovation spread through time and space with the result that not all individuals have equal access to information and innovations. In this view it is clear that a great deal of the variance which forms the basis of Rogers classifications can be explained by variables outside of the individual at an institutional level. This represents a conceptual shift from the nature and activities of individuals to those of diffusion agencies.

A further serious limitation of Rogers model is a product of his individual focus. This makes application of the model to organisations, in which decision making is the outcome of complex processes involving a number of individuals in a structured setting (McGrew and Wilson, 1982), highly problematic.

However despite the insights offered above Rogers still fails to shift his focus of analysis away from the individual. The innovation decision process is presented as

> "..the mental process through which an individual passes from first knowledge of an innovation to a decision to adopt or reject and to confirm this decision."
>
> (1971: 132)

Added to this the pro-innovation bias is still evident. An individual's perception of an innovation may become more sceptical even after adoption as a result of information flowing through social networks. This can lead to what Rogers refers to as "innovation dissonance" and may lead to "discontinuance" Rogers' solution to dissonance is that the individual will seek to alter his/her behaviour and attitudes. (1971: 316) In this process the change agent is allotted the important role of preventing dissonance by providing supporting messages to ensure the innovation is continued. Again this perspective is firmly rooted in the modernisation paradigm that targets obstacles to information flows as the key to the innovation process

> "..the rate of adoption of family-planning innovations has 'plateaued' and declined in several Asian nations, owing to rumours about the side effects of these contraceptives. Such negative messages at the confirmation stage in the innovation decision process may lead to discontinuance"
>
> (1983: 186)

Clearly, in this case, the innovation is seen as desirable and its discontinuance as a product of the corruption of good information flow. This vastly oversimplifies the situation and ignores the fact that population growth and control must be seen within the context of the interplay between socio-economic and political factors and that contraception may not be in the best interests of the poor in developing countries (George, 1976; Bondestam, 1982; Bagchi ,1982; Johnson, 1994). By concentrating on individual psychology and in assuming the natural benefits of the innovation Rogers has simply succeeded in distorting the situation.

Rogers' attempt to overcome his pro-innovation bias is limited. For instance the category of "overadoption" is interesting. He argues that it should not be assumed that the adoption of all innovations is necessarily desirable

> "Overadoption occurs when an individual adopts a new idea under conditions when experts would consider him irrational to do so. Rationality is the use of the most effective means to reach a given end."
>
> (1962: 147)

However Rogers offers no explanation as to why the expert's rationality would be privileged over the user's. In effect he is arguing that inappropriate adoption of innovations is the result of poor decisions by adopters who are carried away with irrational ideas. There may be many instances in which this is the case but he fails to examine the role of 'experts' and suppliers in encouraging such actions.

Later Revisions

Many of the themes outlined above remain constant threads through Rogers work and later revisions tend to take the form of additions rather than reformulations. In 1976 (Rogers and Rogers) he substantially revises his framework to incorporate an number of important elements. Firstly there is a new focus on the context in which innovation takes place. The focus is expanded beyond the point of adoption to incorporate the specific preconditions which give rise to the perceived need for action. Also there is an attempt to address the question of innovation in organisations. The processual understanding of innovation is maintained and developed to incorporate implementation. Thus innovation is now understood not only in terms of technological or administrative objects which may or may not be adopted by an individual but as a process informed by specific antecedent conditions and which incorporates the various moments which span the period leading to the moment when an innovation loses its special status through its absorption into the very fabric of routine organisational activity.

Another important development is recognition of the pro-innovation bias of earlier works. It is noted that previously the innovation literature tended to treat innovation as in some sense an inevitable phenomenon. This view of innovation as always "good" is now recognised as an obstacle to the understanding of the innovation process. Although innovation is now seen to be a highly contingent process, and the decisions surrounding it are by no means unidirectional, Rogers never manages to fully purge himself of his commitment to the pro-innovation bias. Indeed it can be seen that the example of family planning provided above remains in the 1983 edition.

The reformulated model (figure 2) is characterised by a number of features. Firstly, innovation is but one of a number of possible responses by the organisation to a confluence of external forces acting on it. Innovation may not always be the optimum course and other responses may include non-innovative change, expansion or contraction of activities, or no change at all. Secondly, innovation proceeds through a series of closely related stages representing increasing commitment by the

Figure 2: Rogers' Reformulated Model

Aston University

Illustration removed for copyright restrictions

Source: Rogers and Rogers 1976

organisation. There is some confusion over the third aspect. In 1976 there is a recognition that these stages are neither discrete nor unilinear but interactive and subject to an array of loop backs and modifications, however in the 1983 edition Rogers has reverted to a linear view and he argues that stages exist and are chronological (91-94).

As noted above the 1976 model attempts to formulate a processual understanding of innovation and takes the moment of adoption as the starting point. Influential models of innovation as a time based activity have identified two distinct stages and two distinct organisational structures. The stages are initiation (the process by which an organisation becomes aware of an innovation and decides to adopt it) and implementation (the process by which an organisation puts the innovation into practice). Dual structure theories (e.g. Burns and Stalker, 1961) argue that those structural characteristics of an organisation (high complexity, low formalisation, and low centralisation) that facilitate initiation by opening the organisation to its environment make it difficult for the organisation to implement the innovation (which requires high centralisation, high formalisation and low complexity). Rogers and Rogers (and Eveland) point out that such dual structures may be impractical or impossible for most organisations to manage and so they attempt to develop a more differentiated model of the process of innovation.

The innovation process is itself preceded by a period of problem definition in which an agenda of expectations and problems is set. This represents an important improvement on earlier formulations on two counts. Firstly the earlier model held individual adopters to be largely passive actors in a process in which diffusion agencies remove obstacles to information flow and thus to adoption. Now potential adopters are conceptualised as active participants who intentionally scan the environment for solutions as opposed to receptors of information diffused by agencies. Secondly external influences upon adopter units are conceptualised in a more sophisticated way which goes beyond the closed boundaries of individual psychology and community tradition (or by implication organisation culture).

This period of agenda formation is conceptualised in terms of a dual process of problem definition and the formulation of solutions. Problem definition concerns the process whereby an organisation becomes aware of and defines specific "performance gaps" which correspond to an identified discrepancy between an organisation's expectations and its actual performance. Such definitions are subject to variable degrees of specificity ranging from loose, general statements of concern to operationally precise prescriptions for action. The key feature of a performance gap is that it describes a dissonance between expectations and reality. Thus gaps may be created or removed by changes in either dimension. The perception or lack of perception of performance gaps is mediated by organisational context and environment: expectations may, for instance, change as a result of an external shock, for example a change in the market which may create new realities, or a change in ownership or the infusion of new blood which may provide fresh vision and create new expectations. Perception of a performance gap may result from either or a combination of the two.

It is important to recognise that this stage takes place prior to the process of innovation itself. Problem definition is not considered to be a stage in the innovation process itself but rather a precondition for it. The two processes are not necessarily tied in a unidirectional way. This is important because it most clearly marks the shift away from a pro-innovation bias: the outcome of this period may be a course other than innovation. Thus this part of the model represents a contextualising element for a possible adoption of an innovation.

In place of the more usual two broad phases of initiation and implementation the model consists of a number of discreet stages all of which are subjected to pressures both from the environment and as a result of the decisions and actions taken during preceding stages. Five stages are articulated: *matching*, *testing*, *installation*, and *institutionalisation*. Each stage engenders a range of issues and problems which need to be negotiated in the process of the selection of specific innovations at both generic and subsystem level. The adoption decision marks the beginning as opposed to the end of the innovation process.

The first stage involves the matching of an organisational problem (performance gap) with a potential solution in the form of an innovation. This marks a shift from problem definition to innovation proper. The testing stage represents a limited implementation to assess the accuracy of the match and its possible effects. Installation refers to the process of connecting the innovation to the ongoing structure and activities of the organisation. Institutionalisation refers to the process of removing the status of "innovation" from the new element, thus making it an integral part of the system.

Just as the innovation process is developed beyond the two stage model, so too is the influence of contextual factors developed to take account of dimensions other than the structural notions of complexity, formalisation and centralisation. These insights are seen as useful but limited. Three other contextualising variables are considered: knowledge, external accountability and slack resources.

The existence or creation of a stock of knowledge concerning particular innovations and the perception of their appropriateness is seen as an important influence on the likelihood of an organisation bringing an innovation across its boundary and incorporating it into its structure. The existence of knowledge is tied to the characteristics of personnel and to the existence of defined search procedures. The 1976 model marks a crucial shift away from earlier formulations in the recognition of the role of organisational knowledge not just at the matching stage but also throughout the whole innovation process. In particular, the conception of an innovation as a static entity which crosses the organisational boundary to be accommodated relatively unchanged into the ongoing practices of the organisation is rejected in favour of a more dynamic understanding. Innovations

> "...go through extensive revision, essentially amounting to 'reinvention' in the process of their adoption and implementation with the organisation."
>
> (1976: 159)

Thus organisations often adopt not a specific blue print for an innovation but a general concept whose operational meaning gradually unfolds in the process of implementation.

The notion of "external accountability" recognises that the innovation process is not a series of events which occur exclusively within the boundaries of a specific organisation. The whole process is grounded in and contextualised by its links with external networks, pressures, and forces. Thus the "external accountability" of an organisation is an important contextualising concept. External accountability refers to the degree to which an organisation is dependent on, or responsible to, its environment which may be defined in relation to various organisational boundaries. Such dependencies may be defined in terms of the need for funds, specialised personnel, psychological elements (e.g. significant reference groups), and operational dependencies. Operational dependencies may be of two kinds which correspond to the nature and scope of legitimate question to which an organisation must respond. Other externalities include the location of organisations or specific personnel in inter-organisational networks which co-ordinate the flow of knowledge in various forms. For example, the involvement of organisational staff in inter-organisational relationships, over time, which exposes them to new ideas, new perspectives, and experience of new approaches and techniques to organisational problem solving. These connections may be expressed in the form of the existence or establishment of collegiate relationships, or they may be hidden elements in the mobility patterns of key personnel over time. External accountability is a crucial element in the generation of shifts in organisational expectations leading to the perception of performance gaps. In general the greater the number of external accountability relationships, to which an organisation is party, the more expectations it will acquire and the probability of it embarking on a search for solutions is increased. External accountability is also instrumental in the distribution of knowledge and experience across organisations through time.

The tendency therefore of an organisation to generate the kinds of awareness necessary for the identification of performance gaps is closely related to the inter-organisational context in which it operates. The capacity of an organisation to respond to identified problems, however, is also subject to intra-organisational elements particularly concerning the availability of and potential for mobilising necessary resources. The notion of "slack resources" is used to refer to the existence of resources not already committed to other purposes which facilitate the absorption of pressures generated in the adoption and implementation process. All innovations require an investment of resources for their implementation. Thus the existence of slack resources is an essential ingredient in the innovation process. Such resources include financial, personnel, and physical elements which may already exist or may be created. Rogers points out that the amount of organisational slack is closely related to the likelihood of adoption. However, he fails to take account of the effect that different kinds of pressure or slack may exert at different moments in the overall innovation process. It is not the existence of slack in itself that is important but its combination with other general indices and in the pattern of relationships between various types of slack resources. Thus a combination of physical pressure (e.g. increased market demand coupled with financial slack in terms of the availability of funds may facilitate adoption whereas physical slack in terms of a temporary reduction in demand level may facilitate implementation as pressure on the performance of the innovation and organisational personnel is reduced at a crucial moment. Financial slack created through the exertion of pressure on personnel levels is likely to facilitate adoption and yet hinder implementation.

The 1983 Model

The model of organisational innovation that Rogers presents in the 1983 edition of the "Diffusion of Innovations" owes much to the ideas formulated in the 1976 work of Rogers, Rogers and Eveland. However there are some differences.

Rogers defines an organisation in classical and rather mechanistic terms (Morgan:,1986) as a stable system of individuals. It is a stable system characterised by predetermined goals, prescribed roles, an authority structure, rules and regulations, and informal patterns.

Rogers approaches innovation in organisations through the categories of collective and authority innovation-decisions. Collective innovation-decisions refer to "..choices to adopt or reject an innovation that are made by a consensus among the members of a system." (1983: 347). Authority innovation-decisions refer to "..choices to adopt or reject an innovation that are made by relatively few individuals in a system who possess power, status, or technical expertise." (1983: 347). Rogers is still concerned to identify "the characteristics of more or less innovative organisations" and he approaches this issue in the same way as in his earlier work by arguing that many of the characteristics of innovative organisations are equivalent to the characteristics of innovative individuals. For example, he argues that larger organisations are more innovative "..just as are individuals with larger incomes and higher socio-economic status" (1983: 356), although he does concede that certain characteristics of organisations have no individual counterpart. However, he goes beyond his earlier model which focused on individual adoption and considers organisational process by examining the implementation of innovations. This change appears to have been prompted by two different influences. Firstly early attempts at analysis of organisational innovation amounted to the wholesale transference of models developed to understand individual behaviour to organisations. One writer has commented that

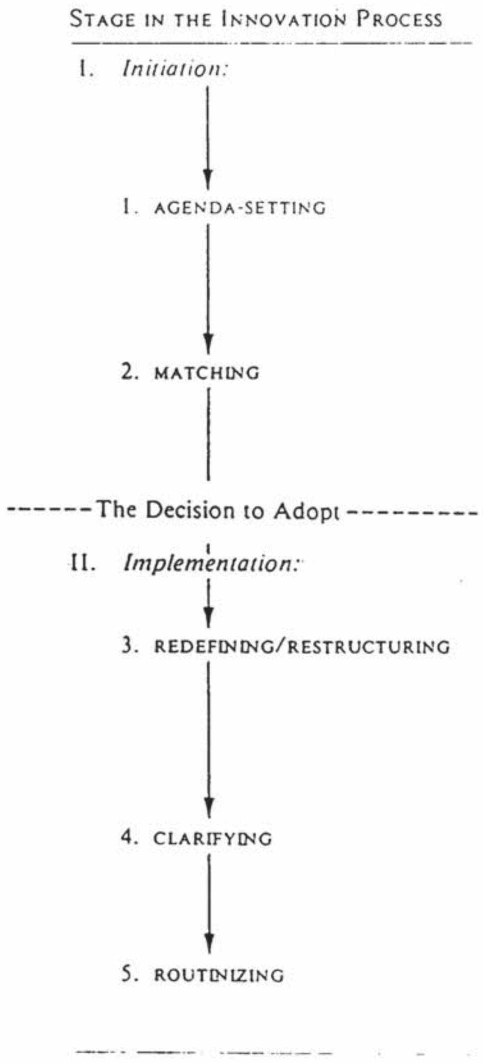
> "...while Rogers' [classical] diffusion model may be useful in understanding the adoption of simple innovations among aggregates of individuals, it appears to be of little value for explaining the implementation of organisational innovations."
>
> (Gross, N., 1971: 22)

Secondly, the shortcomings, in terms of the instability of findings of variance research, which focuses on organisational characteristics like size, centralisation etc., were persuasively articulated by a number of writers (Mohr, 1969, 1982; Downs and Mohr, 1976). Further, other writers have shown how the effects of such characteristics changes depending upon the stage in the innovation process. So structural features that facilitate adoption may hinder implementation and visa versa (Zaltman et. al., 1973) and that the structure of the organisation and therefore its innovative potential is also contingent upon its environment (Burns and Stalker, 1961).

In the face of such difficulties Rogers constructs a five stage model (Figure 3). The first two stages are part of a larger process of "initiation" which is defined as all the information gathering, conceptualising, and planning for the adoption of an innovation, leading up to the decision to adopt. The following three stages form part of the "implementation" process which is defined as all the events, actions, and decisions involved in putting an innovation into use.

The agenda-setting phase is a continuous one and the key characteristic is that individuals identify a *performance gap*. That is, a discrepancy between an organisation's expectations and its actual performance.

Figure 3: Rogers' 1983 Model



Source: Adapted From Rogers 1983

Rogers argues that the perception of such a gap can be a strong impetus to search for an innovation. He also notes that an alternative impetus is March's (1981) idea of solutions looking for problems. In other words that the problem may follow the solution.

The matching stage entails what Rogers refers to as a kind of 'reality testing' (364). This means that a "symbolic trial" takes place during which the innovation's ability to solve the identified problems is tested. This stage may result in adoption or rejection of an innovation.

With the redefining/restructuring stage the implementation process begins and the innovation is imported into the organisation and begins to lose its foreign character as it is 'reinvented' to accommodate the organisations needs and, if necessary, organisation changes are also made to accommodate the innovation.

In the fourth stage of clarifying, the innovation is put into wider use within the organisation and "the meaning of the new ideas becomes clearer to the organisation's members"(1983: 365) and stable arrangements are made as the innovation becomes embedded in the organisation's structure.

Routinisation occurs when the innovation becomes incorporated into the regular activities of the organisation and loses its separate identity. Rogers also notes that at this stage there is also the possibility of "discontinuance" and "deimplementation".

According to Rogers these five stages usually occur in the order presented

> "..until the activity at one stage is substantially accomplished...the next stage cannot begin"
> (1983: 366)

although he does acknowledge that under certain circumstances the stages may appear "..muddled and overlapping". He notes that one important reason for the failure (deimplementation) of innovations is that important stages are neglected, so that, for example, if the clarifying stage is rushed the routinisation stage may never occur.

Rogers then in a succession of publications has produced an elaborate account of innovation as a process. It has been important to show that Rogers' thinking has been developmental and his later works have been expanded to encompass many areas neglected in his earlier ones. However the developmental process has another implication, and that is that the later, revised works, attempt to address the process of innovation in a way that is, in my view, still constrained by many of the assumptions of the earlier work. Further, his attempt to incorporate organisational innovation into this model is flawed as it continues in a highly rationalistic perspective that views the process in terms of organisations searching the environment for innovations: I will return to the problems associated with this approach later. In consequence, although the model provides a useful framework for analysing complex processes it is not sufficient to encompass them and so there is a need for further development. Rogers has been criticised for attempting to explain processes surrounding the adoption and implementation of complex technologies using a model that is barely adequate to cope with the adoption of seed corn in rural communities (Brown, 1981; Grilliches, 1957, 1980). This may be an exaggeration, and a number of contemporary writers still work within this framework (e.g. Pennings, 1987) but it does highlight the problem that Rogers model has in dealing with increasingly complex technologies in increasing complex contexts.

In the next two sections I will examine the adoption and implementation of one such complex technology (CAPM: Computer Aided Production Management) by a number of organisations in order to identify the strengths and weaknesses of this model and to suggest ways of developing it.

CHAPTER 4

Computer Aided Production Management Systems

In this section I will outline the nature of CAPM as it appears in the production engineering literature. The reason for this is that it will provide a useful basis for an application of Rogers' model as there are clear similarities between these definitions and Rogers' understanding of both the innovation and the innovation process. The definitions that follow arise as part of a clear attempt by government agencies to identify problems hindering the diffusion, adoption, and implementation of CAPM systems (ACME Directorate, 1986; Monniot et. al.. 1987; Webster, 1990; Clark and Newell, 1993). The definitions also lend themselves to Rogers' notion of innovations as objects that may be disaggregated and adopted in stages. Given this CAPM represents an ideal vehicle for exploring Rogers' ideas.

CAPM is not an easy thing to define or even to describe. It is a moving feast that differs from time to time and place to place. It has been defined as all the computer aids supplied to the production manager (Monniot et. al., 1987) and is designed to improve the availability of information to the production manager and consequently to improve the co-ordination of the manufacturing process. Although, as we shall see, Corke (1985) takes a broader view.

Monniot et. al. go on to say that CAPM is concerned with three areas of information processing. First, specification which ensures the manufacturing task has been defined, and instructions produced. Second, planning and control which includes planning the timetable, adjusting resources and priorities and controlling production activities. Third, recording and reporting production status and performance for liaison with other departments, and future use in specification, planning and costing.

Further, they say, CAPM systems have the potential to help production managers with their information processing in three ways. Transaction processing, which is concerned with maintaining, updating, making available specifications, instructions and production records. The production of management information, which provides information for exercising judgements about the use of resources and customer priorities. And finally automated decision making.

The applications cover the manufacturing process from the obtaining of orders to the execution of them to the satisfaction of customers (Corke, 1985). The intention is to put the production manager in control so that he/she is aware at all times what delivery dates can be offered realistically after taking account of existing commitments. The information should facilitate planning and ensure that the right materials are ordered at the right time and permit the monitoring of work in progress, and finally to control inventory without forfeiting flexibility.

Corke (1985) lists a number of objectives of CAPM

- To facilitate shorter delivery period
- To meet customer deadlines
- To maximise companies' resources of plant and manpower, balancing required output with cost
- To plan and control levels of stock and WIP at minimum level consistent with above objectives
- To facilitate flexible response of manufacturing capacity

- To provide systematic planning and control of the procurement of material and its progress through the stages of the manufacture
- To provide job satisfaction in place of frustration.

CAPM can be distinguished from CAD/CAM as the former is concerned with systems whereas the latter is concerned with manufacturing plant. CAPM is concerned with co-ordinating integrated functions.

Interestingly Corke identifies two broad dimensions in defining CAPM which he talks of in relation to failure of implementation. He says there are two main reasons why CAPM may fail. Firstly because the computer system is inappropriate to the company's needs and secondly that the management is not applying the principles of production management appropriately in the circumstances of the company. Often, he argues, both apply but the second is more common than the first.

> "This book therefore lays emphasis on the principles of production management as well as describing computer systems for production management"
>
> (p. 6).

According to Corke (1985) the benefits to be derived from CAPM are that it enables individual functions to be performed better through necessitating the clarification of the relationship between system components and facilitates the continuance of best practice operation. Monniot et. al. (1987) note that there are no agreed standards for assessing CAPM and systems may differ in design, implementation, type of integration, level of integration, size, and level of implementation of sub-systems.

Corke (1985) identifies three different types of system: off-the-shelf, turn key and bespoke. Each has different characteristics. Off-the-shelf systems are complete systems that include both hardware and software. They have a number of advantages in so far as they are cheaper, they should have tried and tested software and support facilities, they can be seen in operation before use, and finally they can be implemented much faster.

Turn key systems are ones in which hardware and 'tailored software' are supplied by a single software house to meet an agreed specification . The advantage is that the user should have more control over the way the system works but, on the other hand, specification is crucial and if there are problems it can be very expensive to correct them.

A bespoke system represents the internal development of a new or existing system.

As well as the different types of systems noted above Monniot et. al. identify differences between systems in the level of integration. System integration can be understood in four ways: *Technical integration* which refers to the use of compatible hardware and software; *Information integration* which refers to the use of common data definitions and status information expressed in common currency; *Strategic integration* which refers to the existence of common aims at all levels within the organisation, and finally, *Functional integration* which refers to the merging of business functions. The authors note that although these types of integration are 'logically' distinct, in practice they occur in parallel and are not readily distinguished.

The scale of CAPM systems is highly variable and the in Monniot study the spectrum of CAPM systems ranged from one of two terminals with a file of 300 parts to one of 140 terminals with a bill of materials record of several hundred thousand parts.

Further they found considerable difference between firms in the implementation and use of particular sub-systems.

Figure 4

ANALYSIS OF CAPM (SUB) SYSTEMS INSTALLED TO SUPPORT PRODUCTION MANAGEMENT FUNCTIONS

(All CAPM users in study)

Sub-system	No. of Companies	Percent
Aggregate planning, Master Production Scheduling, Capacity Planning Activities	19	66%
Materials Requirement Planning	23	79%
Inventory Control (raw materials, components, end products	22	76%
Work in Progress Control, Order Monitoring	20	69%
Works Order Printing	20	69%
Shop Floor Scheduling, Operation Sequencing	16	9%
Shop Floor Data Collection	9	31%
TOTAL NUMBER OF CAPM USERS IN STUDY	29	100%

Taken from ACME Report, Table 1 p. 6

They also note there are wide differences in the level of integration of CAPM between firms

Figure 5

LEVELS OF CAPM INTEGRATION

	Level	Definition
0	No CAPM	No CAPM or installing now
1	No integration	Several functions computerised but without regard to integration
2	Partial integration	Several functions linked via common files and co-ordinated activities
3	Full integration	All CAPM functions using common data bases
4	Integration of manufacturing systems	CAPM systems designed in conjunction with material conversion, handling and quality systems against manufacturing strategy objectives

(Taken from ACME Report, Table 2 p. 7)

Specific CAPM systems should be tailored to operate within specific manufacturing environments: for example in some contexts MRP is appropriate and in others it is not.

In principle it would seem that CAPM represents not so much a radical change in production systems as a refinement designed to permit the flow of items through systems to function more efficiently. It is concerned with the system and with the flow through it and with the availability of detailed knowledge of the individual items in that flow at any given moment. It is not located within the realm of manufacturing hardware but of manufacturing systems. It is designed to fine tune systems and to provide the information which enables management to further rationalise decision making concerned with the efficient execution of orders by balancing customer demand with production capacity. It also provides the basis for the integration of related but separate functions.

What is interesting about Corke's definition is that he defines CAPM in terms of its aims and objectives and not in terms of the 'thing in itself'. It will be interesting to compare these aims and objectives with those of JIT and such a definition could be applied to a variety of different approaches to production management that are not specifically computer aided. Thus, we need to look at the specific functions and the way they are computerised to draw out the real definition.

An Overview of Functions

Corke divides CAPM into three broad topics

1. Balancing load with capacity

2. Procurement

3. Control of manufacture

Figure 6 is a schematic representation of CAPM

Figure 6: Schematic Representation of CAPM

Aston University

Illustration removed for copyright restrictions

Source: Corke 1985

1. Master Schedule (or master production schedule)

The master production schedule is a "management commitment to produce certain volumes of finished products in particular time periods in the future" (Burcher, 1981). This is a crucial document as it is a statement of what is to be produced over the coming period. "Its usefulness depends on its realism". (Corke, 1985: p. 7)

2. Bill of Material

This is a file or set of files that contains all the relevant information for each finished product including materials, components and sub-assemblies, lead times etc.

3. Rough-Cut Capacity Planning.

The master schedule operates on a number of different planning horizons and is subject to change in the light of operations on the ground. It is likely to contain firm orders in the immediate time periods and forecasts in the later periods of the planning horizon. As the plans unfold there is a continuous need to balance load with capacity in the utilisation of various resources and this is the function of Rough-cut Capacity Planning. It also provides a realistic master schedule to feed into MRP.

4. Materials Requirement Planning (MRP)

MRP works from the master production schedule and calculates future requirements of material at every stage of manufacture, both made and bought. In effect it converts the Master production schedule of finished products into orders for components etc. It multiplies product quantities in the master production by unit quantities of each material and component (as listed in the BOM, product specifications) and gives gross materials requirements to make the products, deducts existing stock and quantities on order to give net requirements. It provides suggested or planned orders and identifies any necessary changes in the timing of existing orders, usually as a result of changes to the master schedule.

5. Capacity Requirements Planning

MRP provides information about material requirements to make products and this allows for a second phase of capacity requirement planning to be made. CRP requires a production routing or process specification that lays down:

- the sequence of operations to be followed
- the types of resource required for each
- the time for which the resource is required
- the time needed to set up the resources to perform the operation.

Working from suggested or actual orders CRP calculates the time that each resource will be required in a given period of time. It does not take into account actual capacity. The relationship between rough-cut capacity planning and CRP is linear. The former is required to establish a realistic master schedule for MRP which provides the information for the latter which then takes account of existing stocks and is always calculated in units of time.

6. Simulation of future production.

At this stage there is information available concerning what items are to be made, , in what quantities and by what dates. Given the existence of an up to date Work in Progress file it is possible to interrogate the system to identify areas of overloads and under utilisation of resources and provide a basis for management action.

7. Control of Manufacture

The fruits of the above planning processes are dependent upon the maintenance of accurate up-to-date data, particularly WIP, and also on communication between each section of the factory detailing the sequences in which the operations are to be loaded.

8. Production Timetable

Based on the recognition of individual and cumulative lead times.

CAPM systems then can be defined as computer aids to the production manager covering a variety of production functions. A decision to adopt and implement CAPM requires the selection of both appropriate hardware and software which can range from a simple system with a few stand alone modules running on a single micro computer to a highly integrated system with many interlinked modules and many terminals.

CHAPTER 5

Case Studies of the Adoption and Implementation of CAPM

In the interests of confidentiality all informant's and case company's names have been changed.

PlasticCo Case Study

This case study was conducted over a two year period between October 1987 and April 1989.

Antecedents

PlasticCo is part of the PlasticCo Plastics Group which was formed in May 1986. Prior to this and despite a rising demand for plastics in general, largely due to the consumer boom, PlasticCo's fortune was characterised by a stormy period of instability and decline, culminating in serious financial difficulties. PlasticCo was bought by an international company who later jettisoned all its building products divisions in 1985, and following a failed attempt to sell the lot to Redland the then managing director, P.J., staged a management buyout. PlastiCo Plastics has a turnover of £30 Million and employs 650 people. It consists of four operating companies: Rolinx of Manchester and Burnley, L and P of Margate, PlastiCo of Walsall and Westwood of Kent (Toolmakers). The new corporate strategy is aimed at the creation of a unified processing group providing injection moulding facilities in the 50-2700 tonne range spanning the whole process from conception through to component design, tooling, moulding, finishing, and assembly operations. Each of the operating companies now carries the PlasticCo name in an attempt to forge a unified corporate identity.

PlasticCo has been producing compression and injection mouldings throughout the post-war period. Its customer range includes the: automotive, electronics, electrical and business machine industries. Its injection moulding facility comprises of twenty two machines in the 40 - 550 tonne range. Its compression moulding facility comprises of ten machines in the 40 - 60 tonne range and three machines in the 75 - 250 tonne range. Since the take over PlasticCo has been a focus for investment in both technology and reorganisation. The production process is not complex. It involves the transfer of raw material, either pure or with added colour, from the stores via overhead tubes to the moulding shop which contains various capacity machines of both injection and compression moulding types. Here the moulded blanks move to the finishing shop and then on to assembly before going to despatch. Currently quality control is mobile and conducted at every stage in the operation via patrol inspection. Before the change of ownership PlasticCo had seen no CAPM development at all. New machinery investment has included the purchase of eight new micro-processor controlled injection moulding machines and six robot loading attachments designed to pull down overheads and facilitate a uniform cycle of production. Twelve months previously PlastiCo was in a precarious position and facing losses. Operating practices were underpinned by a massive customer base and characterised by an unplanned and reactive approach to production driven by the need to generated short term profit simply to continue surviving.

Prior to the management buyout it seems PlastiCo was incapable of generating the necessary cognitive shifts required to alter direction. The attempt to span the gulf between expectations and reality occurred within the embedded, recursive practices that had come to characterise the company: an unplanned scramble for more business to meet short-term profit requirements. The identification of a performance gap, the fact that PlastiCo was generating sales volume but not translating it into profit, which was to drive subsequent developments required the shock of external intervention in the form of the change of ownership.

Initiation: Agenda Setting

The buy-out was accompanied by a number of developments including the appointment of a new managing director, David Bury, whose brief was to restore the company to profitability through the introduction of modern management practices, initially working alongside a firm of consultants who had been contracted to identify and rectify the causes of PlastiCo's difficulties. The decision to bring the consultants in was made at corporate level, but the new managing director does appear to have been involved in it. Bury says it was immediately clear that there were serious problems relating to organisation, manufacturing, market strategy, and control. The organisation had developed in a disjointed and incremental fashion and he felt there was a need to "get back to basics". In particular these problems were manifest in the unpredictability of the business which was identified as a serious problem: it was possible to look a few weeks in advance but there were great difficulties looking over a longer term. The company was not able to make long range forecasts nor to identify the amount of plastic needed to meet its sales orders, nor to calculate production capacity particularly between the machine ranges. At a second, but equally important level, there was a perceived need to monitor material which is a key factor in the plastic moulding business. It makes up 42% of selling price. Thus the performance gap had been identified at a general level and also at sub-levels where specific related problems were identified.

Bury perceived the most pressing problem facing him as being the lack of information with which to manage the company and he saw the installation of a computer system as the solution to this problem. At group level there was a positive atmosphere surrounding the adoption of new technology and so providing a satisfactory case could be made covering functional and cost elements, funds would be forthcoming thus creating the necessary financial slack. Bury had had previous experience of adoption and implementation of computer systems and he believed he brought with him an awareness of the potential organisational problems. In particular he was concerned with problems which may arise as a result of the attempt to create organisational slack at a moment when all of the organisation's resources were about to be mobilised as efficiently as possible

> "...you can let your business fall apart while putting a computer system in. Especially when you're running a 160 employee business which is not making money, got a lot of problems as well as no order book, no future and a disheartened work force. To actually sit down and put a computer system in and get it all sorted out either I was going to die or the company was."
>
> (D.B.)

The necessary organisational slack in terms of both manpower and expertise was created through contracting the services of a consultancy firm, ROMAN. They were given a twofold brief based on the recommendations of the report that they produced after a two week long analysis of PlastiCo situation. The brief was firstly to resolve the problems of profitability and secondly to install manual systems as a prelude to the implementation of a computer system to handle a full management information system. ROMAN had already been involved with the Group on previous occasions. Although the decision to contract the consultants was taken by the Group M.D. who was pushing for systems development Bury is adamant that he was always committed to the idea and there was never any question of imposition. On this question his views echo much of the literature on the problems associated with issues of ownership and commitment.

> "...unless I and the guys in the top management team want the system to work it will fail. If you parachute a system into a company it will fail."
>
> (D.B.)

Bury based this conclusion on his own past experience of system imposition through the use of consultancy firms. Particularly during his time at Dunlop where, he recalls' the consultants "dropped a system and ran". The lack of follow through led to near disaster and the confusion was compounded by in-house lack of understanding. Bury's arrival added considerably to the organisation's stock of knowledge. Prior to arriving at PlastiCo he had gained experience of system implementation both academically (his doctoral thesis concerned the implementation of a shop floor information system) and through varied industrial experience. This led to a cautious approach to the use of consultants and an attempt to build in safeguards against future problems. Firstly the consultants had been contracted for a period of eight weeks in excess of the implementation period so that they would be on site should early "teething" problems arise. Secondly the financial director, Barry Took, who also had had previous experience of system implementation in other organisations, worked closely with the consultants in order to establish at least some level of in-house familiarity with the system. Thirdly there were clauses written into the contract guaranteeing twenty four hour cover on hardware and software with updates supplied automatically as part of the contract with ROMAN and not the software house. Also clauses were included to ensure the system operated as promised.

The approach to implementation adopted by ROMAN involves the application of a specific methodology, the most important feature of which is the primacy of identified business needs as the lynch pin upon which all subsequent adoption and implementation decisions turn. There are two implicit, basic underlying dimensions to this approach. Firstly, it provides a guiding rationale which threads its way through the initiation and implementation process, and secondly it provides a quantitative basis for assessment of system performance.

Underlying the first dimension is the principle that the process of introducing a management control system through the effective installation of a CAPM system must occur during and not after the implementation phase. If the process is delayed until after the implementation is completed the organisation will have achieved only the installation of a system which has no specific direction or dedication and in consequence a coincidence between organisational requirements and system capability will be essentially contingent.

The second dimension may be seen as an attempt to avoid the ambiguities of assessing a system in terms of intangible benefits. Such assessments are held to arise from a confusion of initial objectives which need to be based on a sound understanding of business requirements which must be carefully and clearly identified and explicitly stated. At the heart of the process of objective setting is the understanding of CAPM as a system which has to be managed in the process of achieving clearly defined organisational aims. CAPM is thus the mechanism through which the company's business plans may be put into practical effect. In this sense CAPM is understood as a goal driven instrument of change. Along side the clarification of objectives it is also held to be essential to clearly define and allocate lines of accountability and responsibility to ensure those goals will be met.

It is possible to view the application of this methodology as a particular instance, in microcosm, of Rogers model. It may be broken down into the following stages:

1 Analysis of business needs.

2 Identification of organisational requirements to meet those needs.

3 Design and installation of a new manual system to meet those requirements.

4 Selection of a computer system which can be overlaid on the new manual system.

Thus stages one and two may be seen to correspond to the initiation phases of agenda formation and matching. The implementation phase does not fit as neatly into Rogers model as the process was much more complex involving both organisational and technological innovation. The implementation has two distinct aspects to it. It might be useful to think of stage 3 as the first level in a nested sequence of implementation in which the identified needs of the business are matched with a new manual control system. This involves the continual redefining of the operations and restructuring of the organisation in the process of clarification of manual operations leading to its routinisation. Once this stage has been reached then stage 4 may seem to represent a loop back to second phase of implementation beginning with a second episode of matching: this time of the manual system to a computerised system.

Thus business needs form the basis for organisation and technological development. The organisation is required to bend not to the demands of a computer system but to the imperatives of business efficiency. The business is bent to match business needs which requires the establishment of an appropriate manual system first "...getting people working in the correct manner." (D.B.) as a prelude to, and a condition for' the later superimposition of a computer system.

Agenda Setting and Matching

The first stage involved a thorough analysis of business objectives and an audit of existing practices to identify and rectify weaknesses in manufacturing and market strategy and organisational procedures. The intention being to bring established philosophies and practices into line with identified business imperatives. For example, a traditional element of PlastiCo practice which had important implications for production scheduling was a strong tendency to meet customer requirements based on informal interventions

> "...what happened was some guy would phone up and we'd drop a tool out of the press and put another tool in....forgetting the tool we dropped was for IBM and IBM were doing £1 million a year with us and this guy was doing £20,000...We'd actually missed the business objective."
>
> (D.B.)

Once identified the problem could be resolved. In this case a classification system was introduced whereby customers were given a grade derived from a number of criteria including scale of business, regularity of orders, stability of schedules, promptness of payment etc.. On the basis of this grading, production priorities are built into routine operating procedures.

> "...Nothing displaces a grade 1 job...the number 5 group are the ones we're questioning whether or not we actually still want to do business with."
>
> (D.B.)

In this way scheduling of work was established on a rational footing which at one and the same time created quantifiable criteria to underpin manufacturing decisions and also prevented the short circuit of business objectives by entrenched, recursive practices. That is not to say that the traditional concern for customer satisfaction was jettisoned but rather that it was located within a new perspective and embodied in operating procedures which reconciled PlastiCo's needs with customer requirements.

> "We thought this business was about meeting customers needs...but that isn't the what this business is about. The business is about meeting PlastiCo's business objectives and if we meet those then we satisfy our customer's needs."
>
> (D.B)

Underpinning the development of these new procedures was a strategic reorientation of the company's marketing strategy. At the time of acquisition the company had a massive and fragmented customer base. After an examination of the customer base and product mix to determine where profit, as opposed to turnover, was being generated the new approach concentrated on the top ten to twenty products and targeted specific market niches. In particular high tech Japanese companies where margins are higher and relationships based on quality as opposed to simply price are more stable. However the strategic shift to the development of a customer base based on quality assurance has important implications for the operating procedures and management control.

Consequently the availability of accurate management information was seen as the single most important requirement and so the existing manual systems were restructured to generate this. The decision to computerise the system was made at the same time to ensure that information was as up-to-date as possible. Thus although no decision had yet been taken concerning specific hardware and software packages the restructuring of manual systems occurred with a view to their translation at a later date to a computer system.

ROMAN's projects are driven by generalists as opposed to specialists. This, they say, is so that user requirements are informed by an understanding of corporate planning, strategic planning, organisational development, operational control, etc.. Specialists are then delegated to operate at a lower, co-ordinated level. This approach is designed to sensitise suppliers to company requirements. It also has the effect of providing an intermediary with whom users can share a common language: a buffer between the technical obscurity of many computer specialists. As Bury explains

> "...Why I like them is they're ex-production guys...been in my job and understand the pressures of what you need to run a business."
>
> (D.B.)

The starting point is the fundamental question of making explicit the reasons for the company's existence and the extent to which the corporate plan (if one exists) reflects these objectives. Once these objectives are clearly defined then the next stage is the development of a strategy to achieve them: turning the "wish list" of objectives into realisable goals.

In order to generate the required information with which to analyse company performance and set company objectives an adequate manual system must be developed and put in place. To accomplish this the board were divided into task teams and given various assignments. For example two directors were asked to determine the standard contribution for the top twenty products. This served two purposes. Firstly to determine profitable areas and secondly to highlight the quality of communication channels and shop floor information "...because this was the sort of data that was going to the computer one day."

The task assignments provided the basis for functional reorganisation into accountable packages of activities with specific responsibilities clearly articulated. For example, material control which drives purchasing and stock control functions of raw materials and finished goods had not been under the control of production. Thus there was a lack of accountability as short falls in manufacturing goods could be blamed on purchasing short falls. In this way accountability was diffused across different functional groupings in grey areas of responsibility. An alternative ideal organisational structure was sketched out between ROMAN and D.B. based on specified functional requirements. Manpower levels were predetermined (a number of redundancies followed) and the four senior roles (production, finance, sales and quality) were filled internally. Thus, save for the temporary involvement of the consultants, Bury represented the only new blood element in the newly constructed top management team.

This process had taken six weeks

> "We really crashed through it. We had total commitment from David, because he was new and had no hang ups about the past, which was a great advantage."
>
> (Senior Consultant)

A position was now reached whereby there was a new organisational structure designed to further the companies business objectives. Lines of accountability had been established and each department had a clear understanding of its responsibilities: 'dimensions' were set up which specified the constraints to be controlled by key people (e.g. certain spend limits, certain targets of capital employed etc.). The organisational restructuring was seen as an essential component of the implementation process because

> "...there was no point in the most brilliant system in the world, computer or manual,...unless the organisational structure is right."

Having determined company objectives and put a new organisational structure into place which was compatible with them the next stage concerned the development and overlaying of an appropriate control system to ensure that the organisation functions properly on a daily basis from shop floor to board level.

Implementation 1 The Manual System - redefining/ restructuring, clarifying, routinising.

The mechanism for the establishment of a control system was the weekly management operational meeting at which the key indicators of company performance were reviewed. These indicators constitute expressions of company objectives and are contained in three information sheets. Great care and effort went into their design, to ensure that the information that is extracted is relevant, summarised and clearly presented. All information had been generated, collected and processed manually in the first instance. This stage of clarification went through a number of stages before the final sheets were produced. The sheets refer not only to detailed operational information like listing of stock or orders but also to summarised control indicators for comparison with pre-determined standards. The rationale was, that if the systems are set up to generate this information and the management act upon it then they are in control. Crucially, although the indicators are derived from analysis of business objectives they are also developed and refined with ultimate computerisation in mind. Thus the information requirements of the organisation determine the selection of software as opposed to the other way around.

It is often cited that many companies believe that the simple implementation of a software system will in itself lead to gains. The whole process of manual system development is aimed at avoiding the problems attendant upon this illusion. Only after the manual system has been set up and is working effectively and the integrity of data is established can the next stage of computerisation begin

> "I'm sure you have seen it in the past. People think, I'm completely out of control, I will bring in M.R.P.. It never works as you haven't got the data and also you may not have the organisational structure to run it."
>
> (Senior Consultant)

The central aim of the project was not to install a computer system but to provide management control. Consequently the computer system was designed to generate highly specified information as opposed to "bits of paper"

> "My experience of the seventies was they collected massive amounts of data that nobody got to...a lot of systems I've seen spew out a mountain of information which is impossible to digest...What we do with the data here is basically crunch it into a two page report that's looked at over a two hour meeting...and we talk problems through. We set more tasks and then we go and look again using the system that's there to help us look for the three of four jobs that are causing the problem. Now if you go and talk to the girl who's doing the job she knows that the job's a problem already. What its actually giving at director level is the indication that there's something amiss...there's no way we're going digging into the system to find problems. The system has to print them out for us and its these key parameter's in running a business."
>
> (D.B.)

The key indicators generated in the establishment of company objectives are the starting point for organising the availability and flow of information. Initially, at the management meetings, the sheets' columns are empty, graphically reflecting the lack of available information and information systems. It is an important element in ROMAN's approach that the rectification of these short comings should not be imposed, or at least not seen to be imposed, by them but derived through a process of involvement of the management team whose commitment and sense of ownership is crucial to success.

> "...you use a mixture of embarrassment, cajoling, and persuasion to make it happen."
>
> (Senior Consultant)

Every level is considered simultaneously. Control documents are designed at every level and each user is trained as to how to collect the information, input it correctly so it feeds the next summarised level up. In the case of PlastiCo, which is a relatively small company, there are only a few levels. Once the key indicators are set and the management meetings instigated then the monthly, weekly, daily or hourly controls are set to drive the data into it. Further, the management meetings are intended to serve to break down departmental barriers as individuals are encouraged to make suggestions concerning other departments. The intention is to encourage people to leave their departmental hats outside and operate at the meeting as an operating team member. This, however, appears to have been difficult to achieve

> "It is very difficult and takes a long time. That meeting has been running since February and it is still not A1."
>
> (Senior Consultant)

The underlying principle is to develop commitment at every level in the organisation to the new system by involving them in its construction. The top management team are made responsible for drawing the information up every week

> "..and making individuals for their areas understand before the meeting what they are going to see so when they are pinned to the wall by their ears they can answer the questions."
>
> (Senior Consultant)

Through the inculcation of commitment into the management team concerning the availability and accuracy of data the intention is to diffuse that commitment further down the organisation. Information is pulled up constantly. Such commitment from the top team is essential as if they cease to ask for the information and cease asking penetrating questions of themselves and of others then the whole system is liable to collapse. If a situation is permitted to develop whereby the shop floor are pumping data up to management who do not read it then eventually the data will develop a tendency to degrade: if nobody notices mistakes, omission etc. then bad habits will creep in. This is why it must be top driven.

At the same time the constant pressure for information generation and flow during this episode leads to a continual modification of the key indicators on the information sheets as it becomes clear as to the actual requirements of management. Thus the sheets were remodelled on a number of occasions as the fit between the organisational requirements and available information is brought closer together.

Although commitment at every level is the ultimate goal there have been a number of problems. During the initial period of reorganisation, which included a number of redundancies throughout the organisation, morale appears to have dipped considerably. Given the fact that such events followed by promises of never again have been common place at PlastiCo, there have been enormous difficulties in persuading the work force that their position is now more assured. Bury has approached this problem with an open style of management aimed at involving everyone in company objectives and developments: every month a review of company status is held with shop stewards and middle management in an attempt to cascade involvement and commitment down through the structure.

Implementation 2: Matching, Redefining/Restructuring

The project has three elements to it: firstly, to return the company to profitability, secondly to introduce appropriated manual systems to facilitate management, and thirdly to implement a computer system to provide the necessary co-ordination of load with capacity, to control material requirements, to control the manufacturing process, and to generated information necessary to facilitate competitive performance through effective management.

The first two objectives are located in the domain of general management consultancy activities and, on the surface at least, have proceeded smoothly and effectively. The company is now performing in excess of Group objectives which related to designated profit levels and return on capital. However, it is difficult to disentangle the various influences in this of improved company efficiency from the effects of savings following the rationalisation process and the slimming of the labour force. The third objective has not been achieved and the implementation of the computer system is widely regarded to have been a failure. The idea was that the computer system was then to be overlaid on top of the new manual system to ensure maximum closeness of match and efficiency of information generation and information flow. The central idea was that the computer system should be designed around the requirements of the organisation, which had already been restructured to maximise efficiency, and not the other way around.

ROMAN formed the view that the company's management information systems requirements could be met by using a micro-computer based approach using the Tetra accounts package and EFAX manufacturing software package operating on Compaq (286 chip) hardware. The implementation involved areas of bespoke software written in an attempt to tailor the EFAX system to match the company's newly formulated procedures and requirements. However the system failed to match the management's expectations of its requirements in various areas of the business and there have been serious problems concerning systems performance.

A number of key problems can be identified: system selection, system performance, documentation and software support, inaccurate information, incompatible software, system design and liaison with consultants, training, morale and loss of faith.

System Selection

Hardware selection was undertaken by PlastiCo's financial director Barry Took. He had previously been involved in the implementation of MRP systems at three other companies. Took was also responsible for the selection of the accounts package. As systems manager he was responsible for ensuring that each module, as it was handed over by the consultants, represented an acceptable and working solution to delineated problems. The consultants, however were responsible for the identification and recommendation of software for production control and management information system. Their eventual choice was EFAX (A software house in Leicester) despite the fact there was no reference site available. In the light of subsequent difficulties this fact caused some uneasiness in the organisation and there appears to have been a feeling in some quarters that ROMAN were not sufficiently experienced in computer implementation and were themselves gaining valuable experience for future projects: the problem of a reference site for EFAX would then also have been solved as PlastiCo is conveniently sited on the M6 motor way.

System Performance

The management appear to have been largely satisfied with the Tetra accounts package. Most problems were with the EFAX system and the interface between the two. The actual process of interfacing was very expensive taking 30 man/woman days and costing £12,000. This was partly because of the inflexibility of the system and this was an ongoing source of difficulties as new requirements for small adjustments arose

> "Well if a customer asks us to do something different, like the example, I mean that its not unreasonable that a guy wants his order number printed differently or wants some additional information, like his full part number not a short code of it. Or he doesn't want our tool number on his label which we normally print on the label. Some guy might decide he doesn't want that, or he wants a bar code printed. This sort of thing. I'm looking at a lot of money to have these changes put in. Its not unreasonable now I think, and no customer has asked for it yet, but the next thing will be if we are going to print a label we might as well agree with it we change it, but we print a bar code on it so he can wipe his pen across it as he enters it into his automated store. That can only be months away in the summer. Now I reckon we are going to be looking at £1,500 - £2,000. Its just crazy."
>
> (D.B.)

There appears to have been an unevenness in the level of performance of different subsystems. For example Sales Order Processing and Stock Control appear to function adequately but the other subsystems do not. Capacity Planning and MRP caused much greater difficulties and it is not difficult to see why the M.D. lacked confidence

> "There would appear to be some fundamental software errors in the capacity planning, and there are occasions where I am getting print outs which will say a month and a half out we may as well shut the place because there's nothing loading on the machines...it moves stupid decimal points..errors still seem to be appearing."
>
> (D.B.)

The Materials Controller confirmed this. Apparently MRP does not work at all and so he abandoned it and reverted to his previous way of doing things. Similarly the production controller says capacity planning could not be used at all.

> "I don't believe it. It doesn't take into account work

> in progress when its calculating what's outstanding...There is no work in progress on the system at all."
>
> (B.G.)

On occasions when it has been run capacity planning is also too slow: it has to be run over a whole weekend, to make rescheduling within a JIT environment possible.

In general users have a very low opinion of the system. The production controller said he found the B.O.M. useful as a library but

> "..apart from that its absolutely useless"

Like wise the materials manager

> "Two years on and I'm still not able to print purchase orders. They're still typed out. In fact its added to the work because we have to run a manual system along side."

Production control continued to be done manually because the system would not perform essential functions

> "...it is so poor I can't tell you from the computer what I moulded last week....there's absolutely no history.....The major disadvantage is tool replacement. You need to convince your customers that its done so much work. There's no way you can tell them that any more."

Response times are extremely slow

> "In fact it's that slow by the time it responds you've forgotten what you were asking it in the first place"
>
> (B.G.)

This was particularly a problem at period ends. For example: a single entry in the recording of operations completed from the daily "crack sheets" was timed at three minutes; backup took up to one and a half hours each day; shop performance reports were taking in excess of four hours per day to generate.

> "You can do it manually on a calculator in fifteen minutes"
>
> (D.B.)

The consultants were not able to pin point exactly the cause of this problem but suggested a combination of the following:

a) inefficiently structured and written bespoke software.

b) undersizing of hardware

c) inadequately maintained files, which may be a reflection of either operating procedures or clear down procedures which should be an integral part of the systems. There would appear to be no file maintenance procedures.

Documentation and Software Support

There was a lack of documentation for the bespoke software. This represents a critical link in the management information chain. This is largely because the people at the software house who actually wrote the bespoke work moved on and also because such support activities are given a low priority by the software house who find new accounts much more profitable. Further, support contact with the software house has been with one person only. The combination of these places the company in a highly vulnerable position. This vulnerability is intensified because PlastiCo found themselves dealing with two software houses. According to the materials manager there is a marked incompatibility between the two and this creates more than just operational problems. There have been confrontations between Exel, who support EFAX, and Computer Land, who support Tetra,

> "..with PlasticCo in the middle."
>
> (K.A.)

There is a lack of management confidence in the accuracy and completeness of the information provided by the system. In consequence a great deal of management time is spent checking the information and running the system rather than using the information provided to manage the company. Keith Andrews, the newly appointed systems manager, is currently spending approximately 60% of his time checking the system and keeping it running: on two occasions the system has "locked out", resulting in a cold re-booting start-up.

Inaccurate Information

A key rational behind the introduction of the system was to produce up to date high level management reports. This has not been achieved

> "..they have never managed to get the software to work...That's what we were paying for."
>
> (D.B.)

Reports were poorly structured and did not provide a high level of management information. As a consequence it was difficult for the management to analyse, for example, reasons for movements in overall shop-floor performance. Bury says that the level of management reporting was higher two years ago when they were using manual systems. Of a planned sixty lines of information the system only generates sixteen. Consequently in many cases they have returned to manual systems. For example the print out from the computer is manually converted into an information sheet by the Works Director: a task which the computer was designed to do.

> "And in a lot of cases I tell you the information I have got now is worse than the information I used to have. I used to get a printout every Monday morning of the previous weeks sales to our customers, I've got to do that manually now."
>
> (D.B.)

Software Compatibility

The system was intended to be a comprehensive, highly integrated system sharing common data-bases, with functions ranging from shop floor daily input to financial and production statistics. Its sub-systems include: production scheduling, capacity planning, MRP, inventory control, WIP control, routing, BOM, shop floor data collection, costing, estimating, quotations, sales order processing, sales forecasting, management information. However this was not achieved. The source of the problems appears to have been a combination of technical and organisational elements. There have been software problems relating to the compatibility of certain functions, in particular the integration of the EFAX production control suite with the financial package. Also the time scale for the input of data into BOM appears to have been badly underestimated.

System Design and Liaison with Consultants

Despite the emphasis ROMAN place on the involvement of personnel at every level in the organisation in the process of auditing the current system and implementing the new manual one (E.g. the people who will be using the information are responsible for its generation and re-ordering) they appear to have had difficulty in extending this principle to the third stage of the process: the overlay of the computer system. This appears to be largely a consequence of their inexperience in the field, which is a new departure for them, and there seem to be two threads to it.

Firstly, during periods of difficulty, for example problems with software bugs, they avoided involving PlastiCo personnel but tended to "...keep their heads down." (B.T.) until the problems have been solved. Their approach was geared to presenting users within the organisation with a completed package ready to run as opposed to involving them in developments. It is striking that although they are adamant that the system is essentially a production system no one from the production department, neither the works manager, the production controller, nor the material controller, have been involved either at specification or at the implementation stage.

Secondly, because capacity planning was initially identified as a key area of company inefficiency they may have concentrated their attention on this component at the expense of others. This appears to have led to both technical and organisational difficulties. It appears that problems arose because the priority to get capacity planning and MRP up and running led to the neglect of other modules on which they are dependent. For example, sales order processing, production control, stock control and purchasing were not yet fully operational and consequently, as Barry Took explains

> "Because they haven't got the SOP and Stock Control running fully MRP keeps having to be reset in Capacity Planning. They are not absolutely sure that the stocks are up to date."

Thus it appears that ROMAN's systematic approach in the first two stages has not been carried through to the third stage.

Also the attempt at configuring the systems to fit the organisation has not worked. For example, product structures held on the system do not correspond to the approach adopted to planning production. Customer requirements are batched to produce economical moulding quantities, the rough mouldings being held as informal stocks to be finished in line with customer schedules. The planning process therefore involves maintaining stocks of rough mouldings, which cannot be recorded on the system as rough moulding has not been set up as a separate part.

Training

This was all compounded by a lack of any coherent training policy. One of the sales order operatives explained

> "There were really no formal training sessions given to any of the people using the system apart from an odd half hour here and a half hour there. This was when the system was here, when it was in. Nothing before. You're talking about employees who have never see a computer before in many cases...that was very poor and it did cause us a lot of trouble with, a lot of errors were occurring because people didn't understand how to use it."
>
> (D.W.)

The production controller complained that the system was never explained to him.

> "There are parts on that system we could be using but no-one explained them I don't know what they are."
>
> (B.G.)

Senior management appear to have resorted to delegation of responsibility, but this created a highly vulnerable situation. Because of a lack of formal training programmes, documentation and user manuals, people had to go through a process of learning by using. This led to a concentration of knowledge among a few individuals.

> "Even if they were very very busy when it happened they should be involved. Alan, one sales director leaves everything to Peter B*****, Chris leaves everything to me, the Quality guys just don't want to have anything to do with the computer system at all... So you have got a very very small nucleus of people with this system using it, excluding Finance there are only seven people and if they leave there would be serious training problems."

This lack of training, during (and after) the implementation process, was reported at every level of the organisation and this made the organisation highly vulnerable to changes in personnel as too few people understood the system. The manager now responsible for the system explained

> "Yes, I think one of the major faults, in a nutshell, of the system we have is that the senior directors, other than Barry Took who has now left, don't know how the system works at all. They don't know how to use it, they don't know how to log on. I think that is a total fault."

Another outcome of the lack of training is that it has resulted in a lack of procedural rigour. For example, there appears to be illogical booking of operations completed in the Works Order File so that according to the file more components are finished than have been moulded. This raises two distinct issues: firstly a lack of discipline in booking procedures, and this in turn may affect system response times if the size of data files is being extended by the number of incomplete records held.

Morale and loss of faith

The effects on people's morale of the continuous problems at a time of great demands on time was significant. The reduction in labour was justified in terms of increased efficiency resulting from the introduction of a computerised system. In a sense PlastiCo appears to have experienced an opposite effect from organisational slack during the implementation phase and in fact, in terms of personnel, organisational tension appears to have been created as the computer system was not installed according to schedule. The development of the manual system and the continual generation of information has meant an enormous amount of work at a time when the firm is operating at below labour requirement. The rationale was that after all the hard work individuals would reap the benefits as gradually the computer took over the arduous and repetitive tasks. The problem is that this has not happened yet and morale is suffering.

> "Part of the problem with motivation has been the fact that people have seen the system fail too many times. They put that much effort in and seen it fail."
>
> (B.T.)

As noted above the implementation took place against a background of rationalisation and so individuals were always extremely busy just trying to do their "normal job" as well as learn to use a system which had failed so many times that there was very little confidence in it.

In organisational terms the preoccupation with MRP and CRP has had a number of effects. It has meant that the personnel who will be operating the various modules after the consultants have left have had little or no involvement or training. This has generated organisation strain and distrust. Lack of direct involvement has meant that the only experience, for example, the materials controller and the production controller have had of the system is distant and tinged with uncertainty as they have seen, from the side lines, the difficulties involved in getting the other modules up and running. This lack of involvement has not been tempered by regular or adequate briefings specifically focused on computerisation and so people are uncertain and worried. It is seen largely as someone else's system, and problem, and there is a measure of concern that the end result of the problems will be that they are left with a system which will not operate properly or flexibly. The production controller, for example, has expressed concerns about the flexibility of the system in permitting the exercise of human judgement in relation to scheduling but to date there has not been enough time for individuals to try it out and assess its suitability. Consequently there is a feeling at some levels that they are being asked to take it on faith.

Discontinuance/ Deimplementation

At the last visit these problems were so extensive that another set of consultants (Peat Marwick McLintock) had been commissioned to produce a report of the system. P.M.M. are PlastiCo's auditors and it was through this relationship that the commission was obtained. Their brief was to review current progress and to suggest options for future development. At the time of writing no decision has been taken but the extent of the failure can be gauged by the fact that the probability is that the existing system will be scrapped and a completely new one installed. As the M.D. put it

> "...Ditch it (The computer system) as soon as I've got something else to take its place. Its lost credibility. I don't think we can do a band aid job..."

PlasticCo have taken on a new manager (K.A.) whose role is to take control of the system ("to try and get the ROMAN System operational" (K.A.) to ease the burden on the Works Manager. There are still problems, for example, in view of his junior position this is a difficult problem for the manager responsible to overcome

> "I've tried, but its got to come from a couple of levels above me. I can't tell a Director he should be familiar with his area, not know it totally, no that is up to his staff, but he should be familiar with what it can do and what it can't do, and maybe down to log on the system and go round, he should be able to do that."

Prior to the Consultants report he produced his own proposals for improvements in the current system. He sees a number of possible options ranging from attempting to continue as now, to replacing both hardware and software. Of these he favours the last and most extreme. He sees the following as the most pressing concerns:

First, hardware: Replacement/upgrading of hardware is seen as urgent in order to safeguard existing usage and to protect the business. Discussions with Exel and Computer Land have not reached agreement on the type of replacement to be considered. One problem is that EFAX does not run on IBM equipment and so this leaves a choice on non-IBM alternatives for upgrade options.

Second software: K.A. argues that considerable improvements are required to the manufacturing system to enable PlastiCo to run a functional integrated system. This is complicated by the quality of bespoke software which according to Exel it is the improvements/enhancements made to the original system which are causing report errors in the data base. K.A.'s conclusion is emphatic,

> "On a more fundamental note, I question the existing suitability of both the manufacturing and financial packages as a functional aid to our business operation, and would suggest that no further time or expense is expended on this software set-up"

The consultant's recommendations follow a similar vein. They are to continue to use the system as parts of it function adequately for the time being. However they have suggested that a specific list of shortcomings be prepared and presented to Exel for their action. However Bury is doubtful if this will do any good

> "and that's dead easy we've been doing that for the last 12 months. But I come back to a comment earlier, a small software house employing eight or ten people is not going to earn a lot of money out of sorting my system out which is not going to be paid for. So what they are doing is working on the green pastures, new jobs where they can make a lot of money. So we don't get priority..."
>
> (D.B.)

They have also recommended PlastiCo to investigate alternative approaches to capturing and analysing performance data, as this appears to the area of bespoke software which suffers from the lowest response times.

Discipline in data recording should be tightened and an in depth investigation of the question of file maintenance procedures should be carried out.

Medium Term Action

In view of the fact that the shape of the company is changing as a result of the opening of a second operation in Gwent and a third under consideration, it is unlikely that the existing hardware and software will meet future needs. Also the division is keen to pursue the use of common systems across the plastic companies. Consequently the consultants recommendations are to commission a feasibility study for a further systems implementation. P.M.M. have offered to prepare a proposal to this end.

The decision concerning which path to follow is a difficult one. Morale has been affected by the traumas of the last two years implementation and staff are reluctant to start all over again.

> "...you could argue that the effort we put into it could have been better directed into improving our production efficiency. The management time and hours and weekends that went into it. Stuffing data in, and running this up and running things in parallel, and I feel quite badly in that I spent what £200,000 of the company's money on this and the exercise around it, and a lot of my people have put in horrendous hours."
>
> (D.B.)

Given the problems associated with the computer system manual systems have been springing up in parallel. Bury is concerned at this because he believes it defeats the original object of producing standardised, reliable management information with which to run the company.

Nevertheless the current system is largely seen within the organisation as being unusable. Bury feels he has learnt a hard lesson and has different ideas about how he would approach the project next time. The approach is underpinned by a requirement for security and safety. The basic components of his new approach would be:

1. Purchase standard hardware from a big supplier, e.g. I.B.M.

2. A simple off-the-shelf piece of software which could be seen running in a similar company.

3. Very little modification to software.

4. Bend existing working procedures to fit the system.

5. Commission one of the large consultancy firms to carry out the implementation. (One who is still going to be there in five years time).

Conclusion

It is clear that the implementation at PlasticCo has been almost a total failure. There have been problems in just about all key areas: choice of hardware, software development, documentation, training and the closeness of match between systems operation and organisational procedures. In consequence the system has not fulfilled its promises, or rather the promises of the consultants.

At the centre of this disaster is the heavy reliance that the management placed upon the firm of consultants. This appears to be have been a focus for political division but this dependence was to some extent inevitable as there was little in house computer expertise, except as users.

> "Because of our lack of knowledge we needed someone like ROMAN to come in and say 'Yes this is what you need' because we would never have had the collective skills to have done it ourselves..but to a large extent we didn't know what ROMAN were imposing upon us."
>
> (B.G.)

This gap has since been filled with the arrival of a systems expert,

> "...the existing staff couldn't converse with the computer people as to what was required so Keith Andrews was essential."
>
> (Production Manager)

At the time however, this dependence appears to have been exploited by the consultants who imposed a system with little or no communication with the users

> "ROMAN never asked what people needed they should have gone round and talked to people." (D.W.)"I do not know who advised ROMAN of the requirements of the production control package. I wasn't involved....We got a computer package which bears no relation to what we do."
>
> (B.G.)

The consultants appear to have embarked upon an overly ambitious attempt at producing a comprehensive and highly integrated system which placed the matching of the computer system to the established organisation system. This would appear to be fine in principle but in reality it would require a great deal of expertise in systems development which the consultants simply did not have. It should be remembered that they were attempting to move into the systems market as an extension of their general management activities. It may well be that their approach rested less on an attempt to match the needs of the organisation with the computer system and more on the attempt to computerise their established general management system which then could be presented as a complete package.

> "Suddenly we found ourselves trying to bend to the computer rather than the computer bending to us."

Clearly the attempt at CAPM system implementation has been a complete failure. What is interesting is that the process has not been a failure in business terms as the company is achieving the objectives it set for itself, albeit at great organisational cost, despite the system failure and this raises important issues that will be addressed later. They have found themselves continually re-addressing the question of computerisation not just in terms of finding a better system but also deciding what they need to computerise and what they do not. Gradually the system has fallen into disuse

> "..the next time you come back to see us we will probably be using an abacus"
>
> (D.B.)

ElectroCo Case Study

This case study was conducted between October 1987 and April 1988

Antecedents/Context

ElectroCo Engine Management Systems is part of the ElectroCo Industries Group. This is a company with a long history dating from its establishment in the 1890's. The 1980's have been characterised by trauma, uncertainty and rationalisation. Up to 1960 the company enjoyed a period of continuous expansion during which time, following a strategy of growth by acquisition, it consolidated its control over the domestic components sector through the establishment of a virtual monopoly. This strategy comprised basically of two related elements to curb competition. On the one hand ElectroCo negotiated agreed spheres of operation with the major European competitor, Bosch. On the other hand, admiration of American methods of production coupled with a fear of American penetration of the U.K. market prompted ElectroCo to attempt to capture as large a share of the domestic market as possible through the application of American methods to the different British situation which could not support an equivalent level of volume. The success of this strategy may be gauged by the report of the monopolies commission of 1960 which catalogues the extent of ElectroCo's grip on the market at that time.

ElectroCo were, however, to pay the price for these long years of growth and stability which was largely dependent upon an expanding British motor industry. With the 1970's came changes in the composition of the market in general and the decline of the domestic auto industry in particular (Economist 24/2/79, Engineer 19/5/83). This was coupled with important changes in the nature of products with the advent of electronics and solid state technology. These two elements combined to undermine the deeply laid foundation of ElectroCo's success based on high volume standardised production in a stable captured market. The crucial issue of the 1970's and early 1980's was ElectroCo's ability to respond to this dual challenge. In both instances the response was framed within the legacy of ElectroCo tradition.

The story of ElectroCo's entry into electronics is an unhappy one characterised by the attempt to wed production engineering philosophy grounded in electro-mechanical understanding to solid state technology. This was reflected in an inflexibility at every level from the board room to the shop floor: the lack of investment; the attempted application of inappropriate production techniques and practices which reflected the "ElectroCo way"; and a general inability to readjust to the requirements of both the new technology and of the restructured market in which ElectroCo's dominance was subsequently eroded.

The attempt to capture new markets was played out in the traditional ElectroCo way through the acquisition of a major interest in the French Ducellier company which was intended to gain a foothold in the European market and provide a platform from which to launch further overseas expansion. Following the failure to establish a controlling interest as a result of the French government's intervention, and faced with the first loss in the company's history in 1981, ElectroCo responded with attempts at rigorous rationalisation in an attempt to cut costs. Reductions in the product range and in the work force were accompanied by plant closures and a merger with S****s industries. A concerted drive was launched to transform traditional production practices and culture along Japanese lines, and the centralised structure of the company was challenged and reorganised into stand-alone business centres.

Initiation

The implementation of a new computer system then, was just one small part of extremely wide ranging organisational and commercial changes. For EEMS this took the form of the ElectroCo "Competitiveness Appreciation Plan" (CAP). Under this plan factories were to become decentralised, stand alone business units. Each unit was required to produce a CAP projection upon which future investment would depend. This was to be the responsibility of the general manager and so it became crucial to be in control of all business costs and expenses.

Originally ElectroCo was using the central, corporate mainframe computer facility but this was identified as a cause of both technical and economic problems. According to the business systems manager it consisted of

> "...a mixture of TSO systems, which we tended to develop in house, IMS systems which tended to be older data-base systems and....COPICS. On that mainframe, those three sections were almost like having three separate computers. You could not communicate between those three sections. To get information from one to the other, we had to extract it over night and use it the next day...that type of thing."
>
> (P.S.)

Previous practice was to write their own software using the central facility. There was clearly an already existing sensitivity to the problems of system development from the user's[1] point of view and including, for example,

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1 The term 'users' here refers to other departments within the factory - storekeepers, production, purchasing etc.

the importance of issues of ownership. The methodology consisted of providing users with a prototype system quickly and then refining in the light of problems generated through use. This was so that users could come to appreciate what their actual needs were through using the system as opposed to resulting from ungrounded speculation. The system would then be refined though an "iterative process" (P.S.) which would also reinforce the sense of ownership.

The use of central computing was charged to them so the more they developed the more expensive it was. Prior to the implementation it was costing £1 million per year.

Thus the decision to move to their own system was prompted by both technical and economic considerations

> "..It was a combination. I would say we could have allocated it so that 60% was the money saving involved....The CAP was the be-all-and-end-all....the other reason was that we felt with the situation of having effectively three systems, we lacked integration."
>
> (P.S.)

This was reflected in a strong tendency for each department to keep separate sets of books which hindered the development of an organisational view over conflicting functional interests.

Most departments had some level of computer support but it was very fragmented. For example, there were three different stock records, one for purchasing, one for standard costing and one for the physical stores. There were also three BOM's, one for procurement and planning, one for standard costing and one for engineering and development. This tended to generate all manner of problems and disputes between functions.

Initiation/Agenda Setting

Against this background of both technical limitations and cost, a case was made, *on economic grounds*, for moving to an in-house computer system. The yardsticks against which the implementation was going to be approved and ultimately measured were clearly identified in quantifiable terms. Only measures which were "meaningful to the business" (Management Services Manager, E.L.) were considered and both revolved around cost or cost savings. The first cost saving was the cost of the central computing facility, and the second was inventory reduction tied to a period of business growth. Because the business attributes 60-70% of its product cost to materials with a stock turn ratio of 20% (five times per year) it was projected that the "real" benefits of the system would be realised in terms of inventory reduction at a time of business growth. However other, organisational, measures were also identified especially to overcome the anomalies of different functional groups using different files

> "The success was very clearly and very definitely that we were going to move as close to the one set of books philosophy as we could"
>
> (E.L.)

Again in developing a specification for the new system the user's needs were paramount and the Business System Manager drew up a "skeleton" which was filled out by the various managers confirming exactly what they would expect the new system to provide for them. This was important for a number of reasons. Firstly it involved the whole organisation in the process and secondly it committed users to the system which they had helped to specify

> "... what we were obviously keen to avoid was the management services doing its famous ivory tower

> act. It had to be an entire factory requirement. We couldn't afford to spend that kind of money and then have users turn round and saying 'Oh, we didn't want it.' It had to be something that everybody was going to participate in, because essentially it was going to be a tool for the business and not a tool for management services."
>
> (P.S.)

It was decided to start with the stores and leave engineering till last for pragmatic reasons. The main problem was identified as materials. ElectroCo products are around 60% material value, 30% Overheads and 10% labour. The plant is basically an assembly operation which buys 99% of its components in. So it was clear that there were substantial savings to be made in terms of efficiency and productivity through material control. Hence the emphasis was placed on stores, purchasing and MRP planning. Also by moving to their own system to achieve this they could, in effect, kill two birds with one stone by taking central computing costs out of the equation.

> "...The concept was hit the problems that are the biggest and easiest to solve first."
>
> (P.S.)

The approach was also driven by a view that it is better to have 60-65% of the system that is needed operational quickly, and gradually refine it up to 90-95%. This enables users to develop an understanding of their needs, and system potential, from using the system.

Matching

A systems requirement document was written in October 1985 which ran to some 280 pages. Following this six potential suppliers were contacted:

ICL, DEC, Hewlett Packard, The Central Computing Group, Xerox, and a Cardiff based firm called WIS. The team at ElectroCo were very clear about their requirements. At this point it was clearly specified that each of the above were to be the main contractor so that problems of responsibility and accountability associated with dealing with different hardware and software suppliers would be avoided.

The prospective vendors were then given access to the site management team for both functional and technical discussions. This was seen to be important so that there would be no confusion over different understandings

> "...so they could understand our nomenclature and the way we were talking about things, what we really meant."
>
> (E.L.)

Between January and May there were user visits to discuss the various supplier systems in practical operation. In March 1986 proposals were received from each of the vendors including a cost and benefit statement and any comments on improvement on the specification.

The tenders were first assessed on "technical merit" by the Data Processing Manager (D. F.). This assessment included things like response times, back-up and recovery considerations, reliability, ability to communicate with other machines, whether they could communicate with a single supplier for both hardware and software, a possible upgrade path etc.. Each system was given a weighting and ranking by the Business Systems Manager in relation to how well they fitted the user requirements that had been specified. At the end of this process it was decided that the IBM System 38 offered by WIS was best in terms of both cost and technical merit. The whole system initially cost £400 - £450,000. This represented a massive saving on the annual charge by central computing.

Implementation

An interesting feature of this case study is the heavy emphasis put on education and training from the very beginning.

> "You cannot stress enough about education and training. If we didn't work on that we wouldn't be where we are today....even down to the point of getting our own senior management educated."
>
> (E.L.)

Training was handled in a very planned and organised way. Having decided to plump for the WIS system 38 the next stage was to undertake "simulation training". There was a clearly identified need to retrain personnel who were all mainframe programmers and systems analysts. In August 1986 a small trial machine was set up, with a "skeleton system", so that users could be gradually inducted into its use. E.L. explains

> "We were able to start our training and start to understand the packages, how they fitted together with teams that we had set up with the working parties."

A "dummy factory" was set up which comprised of two of the shop floor modules so that personnel could be trained in a simulated working environment.

The first machine with the full package, which included product data management (BOM and standard costing), inventory management, MRP ("The standard MRP/MAAPICS number cruncher" (P.S.)), arrived in November. This enabled them to replace virtually the whole of the factory planning, stock control and purchasing system. By January 1987 the full package was implemented and had replaced the COPICS based system. There were some problems initially. The system went live on the 12th of January and crashed on the 13th. This was caused by the attempt to connect incompatible terminals and was quickly resolved. According to Lewis there have been no problems since that day.

Interestingly there was a clear pre-stage to the system implementation which helped to prepare the ground in a number of ways. Prior to the implementation they had moved to a COPICS system on the mainframe and this reduced the number of different data-bases to two: the COPICS data-base with its BOM, and stock and planning information. This was an important incremental step in the innovation process

> "...that was the first step where we actually used a computerised MRP system for the first time. The old planning system wasn't really an MRP system at all...it got people on site used to the concept of MRP and the general principle of you have to have accurate stocks, you have to have an accurate BOM, everyone must have the same BOM...those kind of principles."
>
> (P.S.)

From January onwards the old system went completely out of use and gradually any portions of the old system that were still on the mainframe were brought across and incorporated into the new system. As a consequence of this the bill for central computing fell to less than £40,000 in 1986 and only a few systems are still on the mainframe: sales ledger, largely because this is a complex operation which involves other factories, and the engineering data-base. But there are plans afoot to completely break with central computing.

Resistance to computerisation was not a real problem. Although there were problems at other company sites in the early 1980's over resistance to the introduction of computers, ElectroCo is a relatively new site (around 1982). According to the Supplier Development Manager (S.G.) it has developed as a dedicated one-level electronics factory

> "...being that it was electronics, and as people were brought in they were instilled in the early stages, they were trained that computerised systems were good. And we've got girls on the shop-floor now and they run the actual apparatus on all the different lines, modules, cells, sections within the shop-floor....Now at other factories I've been to you would never get an operator to touch a keyboard to a computer. Its just part of their nature. They were there to put the bits together."
>
> (S.G.)

E.L. believes the earlier experience with MRP was a crucial component in the success of the implementation but equally important was a total commitment from the top. Not only was he completely committed but also other key people like the general manager, factory manager

> "It is the only way. I'm absolutely certain of that....some departments had to be dragged along screaming but that's what management's all about and that's why I say its when the going gets tough you've got to push from the very top. You've got to say you've got to do it.....and you've got to convince people that that's going to happen and they've got to see the benefits quickly."
>
> (E.L.)

There was no transition period when both manual and computer systems operated side by side. E.L. had had previous experience in the 1970's of an implementation of a real time stock control system at a different company and he believes that the decision to have a period of parallel running was a big mistake and, in his view, one of the main reasons for systems failure. This is because at difficult moments operatives will opt for the security of the old system and so the new one is neglected. It was for this reason that the small training modules were set up.

> "...when we went on the 12th January we had nothing else and nothing else to go back to. We told them we've got to make the system work....they either did believe in it or they didn't"
>
> (E.L.)

E.L. is proud that the implementation proceeded well ahead of schedule

There is also a clear indication that the success of the system 38 implementation rested on prior organisational changes which established a philosophy and mode of operation which enabled the computerised system to operate. For example prior to the implementation SOP had completely changed its modus operandi. M.K.(SOP Manager) explains that previously his department was called Sales and Product Planning. As a sales department one group of people were responsible for products on the factory. There was a separate sales liaison section which communicated with the customer. They would receive the schedule from the customer and pass it on to the sales planning people who produced the plan and negotiated with the factory. Now both of these activities are combined. The SOP analysts (there is one analyst for each of the major customers) are responsible for both liaison with the customer and receiving the schedule, for analysing requirements, producing the factory plan, and getting it out to the customer. Procurement is driven by SOP.

> "The point about it is, you see, while System 38 has come in as a computer system, the actual philosophy enabling it to operate was done long before System 38 came along. That's because we had already established ourselves as a body of people, we know the best way to handle the business, i.e. the person who does deliveries does the planning and...there's no finger pointing. You see you have total responsibility, total control over what's going on. You're getting customer information, you're making

dispatches instructions, its all one and the same person."

(M.K.)

Redefining/Restructuring

As noted above this shift away from central computing was in large part a response to the need to bring down overheads in the context of the changed operating environment. This was clearly a highly political issue but the case was made on the basis of the ElectroCo's business needs

> "Once you put a forecast in you've got to make the bottom line. That's what you're measured against....you start to look at how you can make sure you can deliver it. There are a number of different ways. Try to take 1% out of purchase spend and that will put £400,000 on the bottom line. Increase sales by 1% and it won't do a lot...but start to look at some of the costs in the business that we had traditionally accepted because we weren't accountable for the bottom line, we just reported the bottom line. We quickly started identifying some rather...exorbitant costs."
>
> (E.L.)

But another, related reason was to gain control over system development

> "We could put our emphasis where we wanted it and how we wanted it in terms of developing new systems and the nature of the System 38 system itself lends itself to rapid development"
>
> (P.S.)

Originally IBM had suggested productivity gains over standard mainframe development of around 20-30% but the Business Systems Manager (P.S.) was confident that they had outstripped this. Development was much faster than anticipated and another machine was acquired to relieve the main system of the development load. This was built into the original costings for future development but happened nine months earlier than anticipated. The second machine also provided security backup. It is capable of running the entire production system if everything else went down.

The hardware has been very reliable and although there were one or two problems they have not been serious. Nevertheless there are system limitations. MAAPICS was designed over twenty years ago for an earlier generation of machines (System 34). This was a batch machine and although the software has been continuously upgraded its overall design principles are those of batch design. This is limiting because, for example, only one operator at a time may be in actual item maintenance, amending or up-dating bills of materials etc.. This led to the creation of bottlenecks which although not regarded as serious were nevertheless annoying. As a result the decision (November 87) was taken to build on the knowledge base and expertise gained from both mainframe COPICS systems and from the MAAPICS 38 systems which they had written themselves, and effectively re-write their own system and replace the package entirely.

There are two reasons for this. The first is that it will enable them to incorporate the engineering data-base into the system. Secondly, it will enable them to resolve the problems of the limitations of the existing system and provide a basis for diffusing the system to other parts of the group.

Development is not restricted to Management Services. There also seems to be a bottom-up enthusiasm. For example, the Materials Manager has made significant changes to operations since the system was installed including lot traceability, bar-coded labels and a new warehouse transaction screen. The relationship with the Systems department seems good

> "..I tell them what I want, and they work round it.....the response we get from them is superb."
>
> (D.C.)

Routinisation

Now that the system is up and running successfully the team are turning their attention elsewhere. They are now moving towards supplier development as part of the shift to a J.I.T. environment

Success/Failure

In terms of the aims initially set out the implementation appears to have been highly successful. As noted above cost saving was the key issue. The savings from developing an in-house system as opposed to buying in the central facility are easily measured and amount to a saving of around £800,000 per year against which the cost of the system can be off-set (£200,000 per year over three years - total £600,000). In terms of inventory control the stock turnover has been improved from five times a year to fourteen times a year in two years and it is projected to go to eighteen times a year over the following two years. Inventory value has dropped from £5.5 million in April 1985 to £3.1 million in July 1986 at the same time as sales rose from £27 million to £44 million.

They also claim to have made considerable improvements in data accuracy from around 70% to 95%.

It is difficult to assess just how much these successes are due to the computer system itself as opposed to the wider commercial and organisational restructuring which has taken place both before and during the implementation. For example, the ratio of waste on supplies has dropped from 2% to 0.09% and the system makes it possible to monitor this but the relationship with suppliers is something which is developing as part of a much larger drive to Japanese methods and a shift to higher quality, long term relationships with fewer suppliers.

Apart from these bottom line assessments there are other less tangible measures of success. It appears that the system is being used by all operatives

> "If you go along to any of the departments you don't find the traditional red books in people's pockets and bits of fag paper and everything else with part numbers on and shortages."
>
> (E.L.)

There are line service operatives who are responsible for ensuring that the appropriate components are in the appropriate place at the appropriate time.

Conclusion

The adoption and implementation at ElectroCo would appear to have been a text book example of success.

BritCo Case Study

The Britco case study was conducted between July and October 1987.

Antecedents

BritCo Precision is a part of BritCo Foundries Group Ltd.. The group comprises of six companies which together employ 450 people. The group is, in turn, a subsidiary of M.G. Holdings PLC.

The company has a long history originating in the gun trade and its growth and expansion, spanning both wars, has seen both a move into and exit from the bicycle and later motor cycle industries. Precision castings were first produced in the WWII period. The war was followed by a period of enormous growth which established BritCo as one of Britain's major industrial groups by 1969. The collapse of the British auto industry nudged the company into a dramatic decline culminating in the acquisition of part of the group by M.G. in the early 1970's. In a period characterised by positive government intervention into British industry in general and the foundry industry in particular M.G. concentrated on the foundry operations and through a process of expansion built up the BritCo Foundries Group.

The group consists of six companies and supplies S.G., grey, alloy iron, carbon steel, stainless steel, aluminium and non-ferrous castings to specialised component industries throughout Europe and the U.K. In the face of the complex nature of the castings industry the group has developed a corporate strategy which targets each company at specific market niches. BritCo Foundries Group Ltd and BritCo Foundries are located in the North East and represent the group's main iron casting facility. BritCo Foundries (Beverly) focus on aluminium alloy. BritCo Precision and BritCo Incast are located in the Midlands and concentrate on lost wax casting and polystyrene moulding. The sixth company is Deans Power Doors, also located in the Midlands. Each company is autonomous in their day to day running but main board directors are attached to the boards of each of the companies.

Despite a relatively stable world market the British Foundry sector has experienced a dramatic shrinkage over the past three decades during which time a number of major companies have collapsed. Broadly speaking there are two reasons for this. Firstly, Britain has traditionally cultivated a low tech labour intensive base, which consequently has not been able to fight off competition based on cheap labour in Third World countries. Secondly, the decline of British manufacturing in general and the auto industry in particular has resulted in a shrunken home market.

BritCo's corporate strategy had been underpinned by a recognition of this and there has been considerable reorganisation over the previous five years. There has been a shift in marketing away from the traditional declining industries and towards the high tech end of the market. As a corollary to this there has been a move towards the production of specialised products for specialised market places. The customer base now includes hydraulics, fluid handling, nuclear power, automotive, brewing and food, aerospace and general engineering. The unified corporate image, has been cultivated through the financial press and trade publications, and aimed at establishing a group sales and marketing strategy on a group basis. (This may be a significant factor behind recent developments at company level as it establishes a requirement for centralised corporate information). It is now estimated that 80% of all groups products either directly or indirectly (as subassemblies in third party assemblies) go overseas.

Since 1981 the group's fortunes have improved and in 1986 profits had doubled.

Alongside product and market strategy there has also been a major investment in modern technology. BritCo Foundries Ltd has been the focus of a £1.5 million investment in new technology including a new furnace and manufacturing plant with non destructive testing equipment. The is part of an overall £4 million planned expenditure over the next three years (1987-90).

BritCo Precision Castings is an alloy, jobbing foundry specialising in the lost wax process. It employs 130 people. Exports account for a quarter of output, predominantly to Germany but also to Scandinavia and Italy. Long term defence contracts and automotive contracts are important constituents of the home market. Precision has been modernised to the tune of £0.5 million. Since 1984 automated plant has been installed in new buildings around the core of the established factory. Demand for sophisticated finished components has led to investment in on-site machining facilities. Automatic injection presses and robots have been installed in the wax pattern shops and further investment in fast melting units for the casting shops is planned. Automatic plant has also been installed in the finishing shops.

The production process is characterised by a number of stages which operate in various modes including continuous process and batch. The wax room pushes the production process. The work passes from the wax room, which is continuous process, into the shell shop which operates as a batch system. From here the shells go to the foundry which is a smaller batching operation, before moving on to the finishing shop which is again a continuous process.

A CAPM system was installed in 1982. Previously the system was completely manual. Production control was done on a cardex system. Sales order processing was done using photocopies of orders sent around various departments with a copy of the route that the job would follow and a copy of the estimate sheet. Sales would inform production control that there was an order and production control would load the wax room which is the first operation in the chain.

Accounts was the first thing to be computerised in 1982. This was followed by the implementation of a production control suite a year later and then by Sales Order Processing, Works Order Progress/ Order Monitoring and Estimating. MRP, Capacity Planning and shop Floor Data Collection were originally envisaged for a future second phase implementation, but subsequent events may have overtaken these plans. Further expansion of the system is tied to the planned enlargement of the unit's capacity. The above modules are all interlinked and it is planned that this integration will continue in phase two.

All suites have been off-the-shelf with the exception of estimating which has been tailor made.

Initiation: Agenda Setting

There were tentative plans to move to a computer system prior to 1981, but the lack of general enthusiasm for the project is expressed in the view that the proposed implementation was overly ambitious. The managing director, Ian Thomas, expressed deep reservations. It is not clear, however to what extent this unease is a reflection of a cautious and logical approach to adoption or it is more symptomatic of a general fear of computerisation born out of lack of familiarity.

In 1982 there were a number of changes following the arrival of a new divisional managing director who brought with him a commitment to computerisation. He was from a larger company within the group which had had an ICL mainframe for a long time. The main objective initially was to effect labour savings and one of his first actions at Precision was to reduce fixed overheads by £100,00 per annum which led to some staff redundancy and increased pressures for efficiency. The new M.D. saw computers as the means to achieve this. This did not, however, result in large scale redundancies. The numbers in the various departments have, by and large, remained constant but greater efficiency has been achieved and so the same size organisation is processing a far greater volume of transactions. Overall the strategy has paid off. Since 1983 the company's output has doubled but the pressure for greater efficiency continues

> "...from that point of view if we hadn't got a computer in we would have had to have twice the number of people in the mean time...It's doubled the number of orders we're processing, it's doubled the number of batches that we are going through, and it's doubled the number of invoices that are coming in and going out. To have kept the same numbers of people by using computers is a saving, and obviously that's the kind of argument we use whenever our managing

director says can't you lose any more?"

(I.T.)

Given the initial push towards computerisation to bring down overheads the selection of the system and its implementation were left to the newly structured management team. Restructuring resulted in a more functionally integrated organisation insofar as greater responsibility was spread across fewer managers. By this time only two members of the original management team, Ian Thomas and Mike Watson, remained. M.W. took over personnel, administration and commercial functions and I.T. took over production and maintenance functions. The rest of the management team had gone thus removing a potential source of resistance to change (although it is not clear that this was an intentional outcome). The flattening of the management structure represented a shift towards organisational integration of functions and was also accompanied by a spatial reorganisation of departments with a shift to new buildings around the same time. The theme of integration is echoed in the attempt to replace traditional functional insularity with a "company first" cultural ethos which stresses organisational, above functional goals.

The immediate task of M.W. and I.T. was the need to reduce unit costs, and production control was identified as an area where savings could be made. At the time there were five production control clerks whose time was spent ensuring that paper work was generated and goods went through the shop floor and were dispatched. Also there was a very poor stock turn which could be improved through a reduction in inventory and a cut in lead times. Under the manual system it was impossible to identify where the goods were: they went into the system and then six weeks later appeared on their way out of the door. The big problem appears to have been that no-one knew where the work was at any given moment and "an army" (M.W.) of people were employed just to go round and find it. This problem is a reflection of the nature of the business. In any one month there may be three hundred different parts going through the system. A great deal of the work is to DEF 0502 which entails a very long route. Further, routes are specific to each product. Consequently without tight control products will tend to go through the system at the speed of the longest route, which is the slowest.

The combination of Watson and Thomas is an interesting mix which may have been an important feature of the implementation process. Watson displays a flexibility and willingness to change which is in contrast to Thomas's ambivalence and grudging commitment. On the question of introducing the system at all Thomas admits

> "..I was dragged along screaming."

He appears to have taken a back seat in the process. The leading actor in this process was the then financial director M.W. (who has since moved to M.G.)

> "Watson was really the leading light in that. I had very little to do with the choice at the time of the system that we went for. We decided together but really I nodded at the appropriate time to some extent."
>
> (I.T.)

Matching

Mike Watson had arrived at Precision in 1980 as financial controller just before the rationalisation. He had come from a large group (Alfred Herbert) where he had gained experience of accounts and production control system implementation. He describes how BritCo's total reliance on manual systems was an enormous shock to him as previously all he had known was computer systems.

By the time of restructuring Watson had been at BritCo for two years and he recalls being completely aware of the company failing in its reliance on manual systems. The original aim was to implement an accounting system but Watson also felt there was an opportunity to implement a production control system as well and it was with this in mind that it was decided to increase the original expenditure on hardware.

> "So from a whim, to a certain extent, of wanting to implement a financial system we decided that if we could get a production one running side by side....So production control was brought in because we had the existing hardware. The software purchased in modular form was relatively cheap so for four or five modules we could start off. We would have the potential of linking it to a sales order processing system at a later stage."
>
> (M.W.)

The problems before Watson represented a departure from his previous experience of a large company which had written its own custom systems, whereas now he faced the task of buying off-the-shelf. He takes the view that a company should never go for a tailor made system if it is their first implementation because of the problems of organisational resistance around system specification

> "...people view the system with trepidation and they all want to do everything because they know that while all your resources are going into planning, and they're putting more and more things they want into it, the further it goes away from the implementation....If you go to them and say 'Sorry its an off the shelf system, that's what it does.' That's the end of the story. They can't do anything about it. They have to accept it. Once the initial decision is taken that we're going down that road, all the confusion they have, all the worry, which will only mean the channelling of energy into unnecessary things, has gone so all that energy can be channelled into implementing it."
>
> (M.W.)

The other side of the coin is that such an approach tends to result in an inflexible system and Watson admits that this was becoming increasingly evident at the time he left. The top limit of the hardware had been reached and the system is a little slow. The approach he is taking now, at his new plant (Elton Park), will permit a much more flexible development of the system. But at Precision, at the time, such an approach would have been too expensive.

Thus Watson was cautious about attempting an over ambitious implementation and saw the optimum approach as consisting of the implementation of a system of core modules which would permit later expansion. He felt it was important to recognise the extent to the lack of computer awareness that existed at BritCo, and he saw the development of the system and of computer awareness as part of the same incremental process. This incremental approach had two aspects to it. Firstly, it was based on a recognition of the importance of providing space for people to grow with the system in an attempt to minimise the impact of implementation and reduce resistance. Secondly, given the lack of expertise and experience, there were considerable difficulties in establishing at the outset what an optimum system would look like. The principle was that a slow and gradual process would be easier and improve motivation and confidence as one module after another was successfully brought into use, as opposed to implementing a complete system with the possibility that it could turn out to be one large failure from which it would be difficult to recover in terms of staff commitment and morale. At the same time this meant that the development of the system would keep pace with their growing awareness of possibilities. In all an incremental approach was seen to be safer and more flexible.

Watson says they were looking for a computer system which they could fully integrate and which could be expanded at a later date. The selection of the BOS operating system has been a major constraint on choice. Watson rationalises the selection of BOS in terms of the need for a system with a relatively large data-base but which could store it in an efficient manner and for him BOS offered all of this. Out of all the systems that were considered, including UNIX based systems, Watson felt that BOS offered the simplest route in that he saw it to be user friendly and could be easily understood.

> "It was basically an idiot-proof system..."
>
> (M.W.)

However there appears to be another important dimension to the decision to go for BOS. Given that there were no central funds available for this purpose, capital expenditure was a significant factor and this was seen as the cheapest option.

The hardware chosen was Systime (running on the 8086 chip) which was being offered by an agent who was trying to sell BOS. The agent was offering extraordinary value for money and given the financial constraints under which they were operating this appears to have been a major factor influencing selection. The agent went into liquidation four weeks after delivery.

> "I can understand why he went bust. I'm sure he supplied the hardware/software for less than he actually bought it at. I think he was really in financial problems. We had a discount of 30% which is enormous. They don't give you that."
>
> (M.W.)

Although they appear to have got a bargain in the first instance, the choice had serious implications for further development. Specifically when the need to expand the hardware capacity came there were problems as fewer newer systems operate on BOS.

The production control system chosen was a suite supplied by Microsafes who were using the BOS system at the time. DEWTEC had been considered but it was felt that their system was geared more towards calculating yields and the ideal charge, whereas BritCo was less concerned with the melting side because it is not as significant as in the broader foundry industry because the material melting costs are relatively low in precision work. The large number of parts (approximately 4500 at the time) also required a large data-base. Given the jobbing nature of Precision's operations it is essential to store routes for customers who order at relatively infrequent intervals. There is also a requirement for all products sold to the Ministry of Defence or its supplying firms that routes must be preserved on record for a minimum of seven years (DEF 0524)

The selection of the production control software was more difficult than the financial packages for both organisational and operational reasons. On the one hand Thomas, who was in overall charge of production was less convinced of the value of computerising production control

> "Accounts are something I've always thought are better suited to computerisation than production control..."
>
> (I.T.)

On the other hand it was felt that although the software house had a great deal of expertise in production control in general, it was not specific enough to the operating practices at Precision. This was quite clearly a real problem, but also it provides the backdrop against which the organisational tussles, which informed the decision making process, were played out. The problems of matching general principles to particular circumstances provided a foot hold for resistance and narrowed the options for system selection. These factors coupled with a general lack of in-house expertise led to a natural gravitation towards the familiar, and ultimately the decision appears to have hinged on the similarity of the computer system output to the existing manual route card format. This was an attempt to kill two birds with one stone. It provided a yard stick against which systems could be compared and, at the same time, it was hoped it would ease the disruption during the period of implementation by maintaining, at least on the surface, continuity with the past. Watson doubted that this was the correct objective criteria to underpin system selection, but given the lack of expertise and considerable resistance on the part of the production department, from Thomas down, it at least offered what he saw to be a navigable route.

> "Now maybe that's not the right method to go out and choose your production control system, but if you're faced with a variety of systems, none of which are particularly good and tailored to your needs you go for the one that you feel you can implement with a minimum of resistance."
>
> (M.W.)

Implementation

The financial system was implemented in three months. The computer was purchased in June and it was up and running by September. Watson saw this as an important episode because it was the first taste of computerisation that Precision had had and would therefore be significant in the early formation of attitudes

> "The financial packages were installed because once we could install something simple then people would see that, hey this is easy, production control is no sweat."
>
> (M.W.)

There were some initial problems with the accounting system, particularly sales order processing, and this served to highlight some of the problems in dealing with software houses. Jim Finny (Accountant) reported that the relations between Precision and Micro safes were stormy. The package did not work as well as had been promised

> "Microsafes said it was a fantastic system, but it wasn't."
>
> (J.F.)

When there were problems it was difficult to obtain an adequate response from the software house. Finny describes them as "very academic, typical computer people" with no understanding of business and operating pressures. Consequently there was pressure on BritCo staff, particularly Finny and Watson, to teach themselves how to solve problems as they arose.

This notwithstanding, most problems were with the production control suite. In the face of uncertainty Watson saw the key to the implementation and subsequent smoother running of production control system as its simplicity. He was concerned to set up minimum obstacles to users who did not have previous experience of computers. The planned implementation was to be a phased affair beginning with pilot runs, then a short period of parallel running before going completely live. However the course of events did not run so smoothly. Despite the similarity of the new system to the old one, the main purpose of which was to minimise the impact of implementation on personnel, there was still considerable resistance and the period of parallel running became quite an extensive one lasting fourteen months, from March 1983 to August 1984.

Initially there was clearly a serious resistance on the part of the production department to go onto the system, and this found its expression in a reluctance to move on from parallel running. During this time the two systems operated side by side producing both manual and computer paper work. This was because of distrust of the system. This period had important implications for the organisation of implementation and subsequent operation. Essentially, in this instance, parallel running refers to

> "...putting the youngest girl...in a room with a screen and everything that was put on the manual system she put on the screen and inputted into the computer..."
>
> (J.F.)

This highlights two important, inter-related problems: a lack of commitment and involvement on the part of the production department and the implication of this for the design and specification of data input. In the first place the production department was only peripherally involved in the design of data gathering and so input variables were modelled on existing practices. The result of this was that they initially found themselves buried in a mound of information as one operator was spending all day, every day, inputting data. So much so that it was difficult to use the system for the job for which it was intended because no-one else could get at the screen. The heart of the problem lay in the attempt to transfer the manual system wholesale to the computer system which simply meant they were attempting to input every operation, around eight, from the route cards immediately they appeared. But this was causing enormous stress and the problem was solved through the selection of certain areas, for instance inspection operations, heat treatment operations, and mechanical casting operations. These occurred every other operation and so, from this information, a component's current location could be deduced. This had the effect of halving the amount of data input.

Secondly, it established a gulf between the production department and data-processing, between the manual and computer systems, which served to reinforce the distrust felt by the production department, and to draw out the period of parallel running as problems with the computer were not seen as production problems. The production controller had no direct contact with the new system. In effect he carried on as before and inputting of data was seen as someone else's problem.

> "I think people always feel happier with what they know...I think it was very much the case that we've been doing it this way for twenty years so therefore why shouldn't we carry on doing it this way.....people were still reluctant to change. People felt safe, people knew the old system...plus the fact that people didn't fully understand it."
>
> (I.T.)

The reluctance of people to involve themselves with the system was a big headache for Watson. This was in part a consequence of the lack of support from the agent who sold the hardware and the operating system. This meant that Watson was dependent upon manuals and his own efforts to familiarise himself with the equipment and sort out problems as they arose. In effect the system was his baby and

> "...for the first two years any fault and I would have to go and solve it. It was my problem, you know, like if the computer went down it was 'Your computer's down'. There was this resistance and it was only through time they gradually came to see, yes, its a pretty decent thing. Its saving us a lot of work....but it took them a long time to accept it."

(M.W.)

In an attempt to break the rigid identification of the system as his, Watson introduced a hierarchy of problem solving responsibilities. He still took overall responsibility for the system but operatives were eventually given specific responsibility for their modules. For instance if something went wrong with the production control system the operator would be responsible for contacting the software firm. This was intended to develop a feeling of ownership amongst the operatives.

The implementation of the system had implications for shop floor activities, as well as clerical organisation, but changes were difficult to push through in the face of resistance not only from the shop floor but, at first, from Ian Thomas also. Much note has been taken of the importance to system implementation of commitment from the top (e.g. ACME, CAPM Report), but this understanding rests, at least partially, on the assumption of discreet hierarchical increments in lines of management. In this case the signals were confused because lines of authority were blurred as neither Thomas nor Watson were in overall charge. Thus there was a tension between levels of commitment at the top which had serious implications for the implementation process. For example the availability of detailed information made redundant the role of progress chasers who could be freed for direct production work, but given the nature of the business and the unevenness of the monthly cycle there was considerable concern about the reliability of computer data.

> "I was dead set that we couldn't exist without progress chasers. I thought that BritCo was going to collapse without progress chasers...and more sleepless nights and it was fine, fine because we had the computer system and we were getting information back telling us where the jobs were. Print it up on screen, its there."

(I.T.)

However running the two systems in tandem was causing stresses which forced the issue. Firstly, by running both systems together they were inevitably increasing everyone's work load at a time when they were already stretched. Secondly, the manual system was seen as a kind of insurance policy in case either, the information on the computer system was inaccurate, or the system collapsed. But in practice people simply worked with the manual system, which was familiar to them, and ignored the computer system. It was this that forced them to abandon the manual system completely. However there was still a great deal of fear and distrust and the cardex system was stored with a view to rapid reintroduction if the system failed

> "I as much as anybody else thought God what's going to happen...Production control and myself said well never mind if its an absolute and complete botch up we'll go and get the cardex back in again in a couple of days. We were still hedging our bets so to speak and yet we never once referred to it again."
>
> (I.T.)

Finally, despite resistance, with pressure from Mike Watson the decision was taken to go live from the beginning of the financial year, August 1984

> ""...come hell or high water we would go live and the decision was made and people were told and, of course they didn't like it and they said it wouldn't work and we said it will work...and we went live and it worked."
>
> (M.W.)

According to Watson the result was that stocks were brought down £330,000 to £167,000 at a time when the turnover had risen from £2.5 million to £3.5 million.

It is interesting to note the existence of organisational slack which helped to reduce the impact of jettisoning the manual system. Going live coincided with a "lean period" when there was not so much work on the floor. This provided the breathing space to adjust to the changes, e.g. no progress chasers, and build up confidence in the system.

> "We then picked up our output and we remained in control and because it had started off when we were at a relatively low level of output now that we're twice that level of output we've got faith in the computer."
>
> (I.T.)

Redefining/Restructuring

As mentioned above Thomas and Finny felt that accounts are better suited to computerisation than production control because of the greater standardisation of operating procedures across companies and they were of the view that production control suites always cause the most difficulties because standardisation cannot cope with the real differences between companies. It is because production processes tend to develop in a context specific situation that computerisation, particularly off-the-shelf systems, often precipitate a great deal of change in well established practices. In the face of this the immediate reaction was to attempt to alter the system but this soon gave way to the realisation that it was people who would have to change

> "...there were things which we had to change...things at the time that we thought were so tremendously impossible for us to surmount, you know that we'd have to change the computer system and we sat there and said no the computer is dumb. It can't change it's ways. We'll change ours and we did and we found that things worked much better."
>
> (I.T)

Organisational changes, which included shifts in areas of responsibility, had implications for the well established informal operating procedures. One example was the way in which work was booked out. Previously production control were responsible for raising invoices. It became standard practice to forward book work to even out the fluctuations in volume of finished goods throughout the monthly cycle in order to keep the M.D. quiet. In effect the dispatcher was booking out jobs which had not yet reached him. By monitoring jobs on the shop floor he was able to see what was in the system and then raise an invoice which he would sit on and not send out until the job came along. In this way the appearance of even distribution of work throughout the month could be achieved. When production control was computerised responsibilities for invoicing were shifted and production control only raised the dispatch note. Under the new system the invoice was not raised until a copy of the dispatch note goes back to the accounts department. So the accounts were in charge of invoicing and as soon as an invoice was raised through the system it went straight to the ledger and became due in twenty days. Problems then arose because forward booking now meant that the accounts department were unable to invoice work for which dispatch notes had been piling up. The effect of introducing the system was to synchronise formally what only appeared synchronised on paper by drawing attention to practices which obscured inefficiencies. As a result measures were taken to ensure that the castings were packed and booked out ready to go before the dispatch note was raised. In this way dispatch notes and invoices are run off at virtually the same time. Thomas has ambivalent feelings. Although some of the flexibility afforded by the manual system has been lost the introduction of the computer system introduced a more disciplined approach through increasing awareness of problems.

Even so, although the formal system was operating as it should, informal interventions had not been eradicated but simply gone through a shift. This may be a consequence of the fact that with Watson's departure Precision also saw the exit of the locus of commitment to the system that was never embedded in organisational procedure. The computer system generated information which reveals the actual state of affairs, but did not change the fact of fluctuations of volume over the monthly cycle. This, in effect, meant that a lot of work is booked out at the end of the month, and then in the first week of the next month the system is filled up again, and then there is a period of hectic activity to get it out at the end of the month.

However, although computerisation revealed the discrepancy it does not appear to have resulted in a fundamental shift in practices. On the contrary, the informal systems have developed to overcome the problem. There is an admission that they still do the same sort of thing as the end of the month approaches the dispatcher keeps his own informal record of work in progress which he feeds to Thomas in order to allay his fears about meeting targets.

The bulge effect at the end of the month is still a fact of life and for Thomas the computer system is not a good enough guarantee that monthly targets will be met.

> "My sleepless nights are caused by the fact of wanting to know whether in that fourth week we are going to get that (last) £100,000. So this unofficial figure which he gets out is sort of saying well OK there's all that work there that's going to be worth £100,000. Don't worry. Have a good nights sleep. What I worry about is if we didn't do that he'd say 60, 60, 60, 60. Oh God we're £40,000 short on the last day of the month and what are we going to do. It's too late to do anything about it."
>
> (I.T.)

In an effort to overcome this problem a separate manual system is still being run alongside the computer system even though the parallel running period is over.

> "We're running a manual system if you like, an informal manual system, alongside the computer system which is giving us our additional information. If we had the courage of our convictions we'd get to know that the information we were getting off the computer was telling us the same thing because we have production sheets which tell us how much is in the foundry's cast and how much the wax room have produced and we know how much the value of the work being scrapped off...Now providing you're not increasing or decreasing your WIP stock you know that you should be able to get that amount of work out of the door."
>
> (I.T.)

WIP is monitored at the end of each month from the figures of the output of the various shops and the usage of raw materials etc., but there is a reluctance to trust the accuracy of the data.

> "I suppose having been in charge of production for five years one could say OK well you get this gut feeling its going to be right but I'm unwilling to risk it...I need to pay my mortgage. So from that point of view I run a manual system along side."
>
> (I.T.)

There were technical as well as organisational problems with the process of data entry. The manual system had imposed very little limit on the amount of information which could be recorded on route cards. Whereas the process of computerisation entailed an imposition of limits in terms of finite amounts of space available for description of parts, materials etc.. But also the off-the shelf suite had difficulty in coping with the irregularities common to the production process

> "If you like silly things. We had a system originally where if you had a hundred castings in a batch, what can happen here is when we have commercial castings

where no batch identity is maintained, if you have two batches going through of a hundred castings what can happen is you have one batch come through at eighty and the other batch comes through at a hundred and twenty."

(I.T.)

The fact that a batch came back with more than it started with would cause the suite to corrupt and led to both software modifications and to changes in working practices. However, the general mistrust of the system meant that it was difficult to change working practices to adapt to the use of the system. For example, there is no shop floor data input and so each job is followed around with a card and, as each stage in the process is completed, a slip is torn off, signed and delivered to the data processing operative. But it has been very difficult to train staff to return accurate sheets at the right time although the D.P. operative now says

"I've got most of them well educated now, by pestering and chasing them. I don't get them all back now but I get most of them."

(S.H.)

There are also problems over the level of integration of various modules (suites). For example the production control suites did not properly link up with S.O.P. so that there was not automatic updating of related files and this had to be done manually. The software suppliers appear to have been working on this, but "reluctantly" (S.H.) Finny says that part of the problem is that the system is so vast that a great deal of detail has been overlooked

"They sold us a system that doesn't actually work. It may sound very good on paper but when you get into the nooks and crannies it breaks down"

(J.F.)

There are also problems with the system corrupting when asked to so 'simple' things. For example orders cannot be increased or dates changed without causing problems. When a corruption does occur it has to be corrected manually but may still cause problems by not feeding through to all relevant files. Given such problems there is still a lack of trust and so operatives cope by improvising to get the information they need

> "You don't use it...we use S.O.P. instead which doesn't have all the information but you can trust it."
>
> (S.H.)

The production controller is adamant that her job would be a great deal easier if information held within the system could be more widely shared

> "Its silly things really. You expect it to be there and its not."
>
> (S.H.)

Given problems like these relationships with Microsafes have at times been strained and a users group was set up to improve communications between suppliers and users and to encourage Micro safes to improve the system. This development was an initiative of the users

> "To bring it all out in the open. All the problems we have and all the promises they've made and not kept."
>
> (J.F.)

The off-the-shelf package has proved inflexible and bespoke additions are problematic as they are expensive and need to be rewritten after every up-grade

BOS

The choice of BOS turned out to be a mixed blessing. It aided the implementation process insofar as it permitted the use of software which best mirrored the existing manual system and provided an environment which was user friendly but on the other hand it caused problems in respect of upgrading. They were using Systime hardware but in phase two they were talking about switching to a 386 chip. With the 386 Systime will not be using BOS. This causes problems because it means they will either have to look for alternative hardware suppliers or face the prospect of starting again from scratch with new software. Given that Mike Watson has since moved on, further innovation rests with Thomas who has always been a reluctant partner in the process and is extremely cautious about embarking upon another period of change.

> "Whether its the right system or not...we have got BOS in, it works well for us after a lot of heart ache at times...we feel we want to stay with a system which will enable us to build on what we've already done. Rather than going to somebody who has got to start from scratch and tailor their own or custom write the suites for us, which I've got no doubt whatever the claims would cause us problems. Whereas we feel we've got the basic building blocks down already. Provided we can get ourselves some more capacity on the computer we can put things in as we want them...The idea of business is to make money. We do that. We make castings. We've got a system which enables us to do that. Its not that we're in total disarray. We know what we're doing isn't as good as it could be but it means we can build on to it at a sensible pace."
>
> (I.T.)

Clearly Thomas is now as firmly attached to the current system as he was to the earlier manual system.

Assessment of success and failure

For both Watson and Thomas success was related to the generation of management information. Thomas was more concerned with operational requirements. In particular he saw the most important function of the system as the generation of management information to enable them to keep track of the multitude of jobs that might be in the pipeline at any given moment, and to enable track of progress on delivery dates etc. and particularly with regard to monthly targets. This was extremely difficult on the manual system

> "So we're always up to date in knowing what we want to get out and what we can get out for the end of the period which is what we live by really, the end of the accounting period. That's the main piece of information."
>
> (I.T.)

Other information includes figures on labour utilisation, end of the month management accounts, and also customer information. It is in this area that new possibilities have also arisen and there is an awareness that there is a great deal of valuable information concerning the volume of business which can be analysed by region, industry and period which is valuable for marketing information. (It is not clear to what extent the previously mentioned establishment of divisional marketing function has contributed to this awareness). Previously this information would only have been available by employing someone to go through the invoices each month. Given the complexity of the business this would have been prohibitive to say the least, as it is not uncommon for there to be a hundred different jobs for a particular customer.

The installation of the system has had beneficial effects on arrears which, although not eradicated, did come to light more readily making action possible.

Watson places greater emphasis on the need for control for the purpose of the maximisation of long term profit.

> "...in the final case capitalism is based on the ethic of maximisation of long term profit and always at the back of my mind was the bottom line, not the immediate bottom line...There was always a need to control the beast. We needed to control it to know what we were doing, to tune it up. We were a limited management and we wanted the information to enable us to manage...every resource."
>
> (M.W.)

What is not clear is the extent to which these views were incorporated into a clear set of objectives at the beginning of the process and to what extent they are retrospective assessments.

One thing that is clear is that the episode has been an important learning experience for Ian Thomas who has revised his views on computerisation as a consequence. Of particular importance here was the expansion of his responsibilities with his move to M.D. following Watson's departure. In particular he admits that originally he was much more production biased as opposed to taking amore generalised company perspective

> "...as production manager...I couldn't give a monkey's about what difficulties accounts are having, but as managing director it is my concern, so from that point of view my attitudes have changed, because my responsibilities have changed. I suppose mine is a classic case of somebody being dragged kicking and screaming into computers and now sees the benefits of them."
>
> (I.T.)

Interestingly these benefits are of two kinds. One is increased efficiency as a result of the availability of management information. The other is what he calls the "professionalism" by which he means meeting the expectations of customers who expect to see the trappings of modern business approaches.

Group Developments

As already mentioned the implementation was prompted by the problems Precision was experiencing, and was first and foremost an exercise in cost cutting. The implementation does not appear to have been linked to a divisional initiative on a broader front and Redditch was not seen as a pilot for the rest of the group. Thomas was clear that each company would proceed independently

> "We are completely different organisations. We are autonomous companies."

Currently only the accounts side is computerised at Darlington and Beverly and the production side is completely manual. Thomas explained that it is because of the very different nature of operations. Darlington, for instance, has a much smaller customer base and tend to run long schedules. Much of the work involves long dedicated runs and so scheduling is not as complex as at Precision where jobs are often switched between machines three of four times a shift and the number of longer runs are very few.

Beverly and Darlington have bought Olivetti systems. Initially Thomas explained that the only reason that the other two companies both went in for Olivetties is that the ICL at Darlington needed updating and Beverly had no computers at all and so as they were both looking around at the same time a joint venture was logical.

However between July and September (1987) things moved on a pace and the decision to computerise production control at other companies within the group was taken at Divisional level as part of a central initiative, and compatibility of systems was given a high priority. Precision had not been consulted on the specification of the systems

> "...I was horrified that they were going ahead and trying to find production control systems without having asked BritCo Precision anything about its system and whether the systems they were looking at were compatible with what we are running...The first I heard of any integration on computers was last Thursday when I was told we ought to try to get a production control system that is compatible. Its a bit like turning round to me and saying we are going to fly to the moon next week."
>
> (I.T.)

The shock was all the greater because Precision were in the process of selecting new hardware to provide the extra capacity they needed to expand their existing system. Given the difficulties with BOS it seems that Precision will have to change. Thomas was very worried about this development and felt that compatible production control systems were only a partial objective.

> "The reasoning behind it is obviously so that Darlington can flick into our, they want to be able to get into our computer to get figures off for themselves, centralised control."
>
> (I.T.)

This is consistent with the observation made at the outset concerning the development of divisional functions. It is clear that such systems integrated at divisional level facilitate the possibility of federal control.

FoundryCo Case Study

This case study was conducted between October 1987 and April 1988

Antecedents

FoundryCo was investigated at both Group level and at operating company level (P.B. Metals and FoundryCo Derby). FoundryCo PLC is a holding company. FoundryCo is split into two groups of companies: Consumer Products (Lawn mowers etc.) and the other is Engineering Products (previously referred to as Foundries). There have been recent acquisitions like New World Gas Cookers and it has divested itself of some small engineering businesses. Group sales are now in the order of £250 million per year.

The Engineering Group contains five foundries. FoundryCo Derby at Derby, P.B. Metals, Darcast foundry, FoundryCo Castings in Birmingham, and Stirling Metals based at Nuneaton. These companies operate as autonomous business units on a day to day basis but policy is established in the centre. Two are ferrous (Derby and Darcast) and three are non-ferrous and produce a variety of products. The single largest product , in terms of value, is cylinder heads and blocks.

90% of the Foundries Division output goes to the automotive industry. The other 10% is mainly aerospace and defence related. There are around 100 customers but most of the business is concentrated on the big customers. Ford accounts for £12 m, A.R.G. for £10m and Jaguar for £7m. Most of the production is high volume casting although there is some jobbing in the non-ferrous operations. At the moment only 27% of production is for the export market and this is split roughly equally between America and Europe.

The fortunes of FoundryCo have been tied to those of the British auto industry and the foundry industry which is greatly dependent it. The sector has undergone a major crisis and there has been an enormous shake out since the late 1970's following the migration of the British car industry from the U.K. to Europe. For example, Ford began sourcing large proportions of the cars sold in Britain from Europe (Spain and Germany). General Motors virtually stopped being a customer in the U.K.. This situation may now be changing and there may be some shift back to Britain.

As a consequence FoundryCo Foundries is now (1988) half the size it was in the mid 1970s. There have been significant changes in business fortune over the last three years and the business has stabilised and is showing a profit although it is still not achieving the group target levels.

Two companies within the groups have installed integrated on-line computer information networks and a third site has introduced a 'one-input system' whereby the data-base is updated instantly by an input from any stage in the manufacturing operations. All computing is based on the Group's mainframe computer and computing strategy remains the sole preserve of Group central computing function which has directed development since the early 1970's.

P.B. Metals

Corporate Information

P.B. Metals manufactures aluminium castings using the gravity die process and the polystyrene process. Some of the castings are sold in their 'fettled' form for the engine manufacturers to machine but some castings are also machined in house. The existence of the machining facility has proved a strong selling point as this fits in with engine manufacturers current preferences by cutting out the machine shop middle man.

The company's turnover is £10 million of which 35% is for the export market and the rest for the home market. The major export customer is Saab Scania and the next largest is Ford Spain to whom they supply manifolds and water pumps. The actual purchasing is done by the Ford Organisation in the U.K.. They are a volume producer and 100% of production is for the automotive industry.

The total number of employees is 281 and this breaks down to 229 works employees, 46 staff members and 6 directors.

The Company had been through a very rough time between 1979 and 1983. One year saw losses of three quarters of a million pounds. There followed big changes at board level and a cut back to "skeleton" staff levels at the height of the recession. They returned to profitability in 1983 and this has been improving ever since. In the past twelve years overall activity in the domestic gravity die industry has halved but P.B.'s tonnage has remained constant: the market share has doubled in that time. The actual market share is around 11%.

The customer base is largely split between ten large customers. In the first three months of 1988 total sales were £2.445 million. Of that £840,000 went to Ford U.K., £500,000 to Saab, £348,000 to a machinist, which is split in half between castings destined to A.R.G. and Ford. £212,000 to Jaguar, £147,000 to Ford Spain, £135,000 to Ford Germany, £47,000 to Lucas Girling, £45,000 to Bosch, £34,000 to another machinist, £20,000 to Daf, and £16,000 to the rest.

There has been a great deal of investment in automated technology over the last ten years. This is partly due to the need to improve quality standards, but also labour policy

> "Where casting production is concerned, we tend to take out as much skill that needs to be put in by a man as we possibly can and replace it with sophisticated machinery"
>
> (A.P.[Production Manager P.B. Metals])

Computer Systems

The commercial functions were the first to be computerised. The most recent implementation is production control which was underway at the time of interviewing (March 1988).

FoundryCo Derby

Corporate information

FoundryCo Derby operates three foundries which supply a variety of ferrous castings in high volume to the motor industry. They do not have machining facilities. There are seventy five customers altogether but only eight major ones. These are A.R.G., Ford, Lucas Girling, Perkins and Bendix (France), and three machinists. This accounts for 75% of the total business.

The annual turnover is 32 million and there are around 1000 employees on the site. The early eighties were a difficult time. One plant was closed and the others were on four day weeks and short time working throughout last winter (1987) and it is only in the last year that business has begun to pick up.

Computer Systems

There are parts of the system not required at all by Derby. The main usage of the system is for accounting and the commercial functions. There is no production planning as such

> "We have to do our planning by getting information out on sheets and then starting to sit down and study them all and so on...I suppose we could do with it but I think we've about got the thing full at the moment..."

Initiation: Agenda Setting/Matching

A.M. (Finance Director) has been a key figure behind the development of computer systems at FoundryCo. He had no previous experience of computer systems and is an accountant who says he learnt as he "went along." Working with A.M. on systems development has been M.E.. His background is in management accountancy but he has been responsible for the design and implementation of all the computer systems across divisions. He is not a computer specialist. The decision to have an accountant at the helm was calculated

> "...originally we had computer specialists but we found they got into a hell of a mess trying to design management accounting systems. We found it was much more sensible to have someone who was not a computer specialist who understands the business, understands management accounting, he also understands a lot of the production problems and under him he's got a team of computer specialists"
>
> (M.E.)

The road of in-house development was chosen because there was no other option available to the foundry industry in the early 1970's.

> "Because of our shear size in the foundry world we couldn't find anybody. There was nothing, anywhere in the foundry business. Nobody would design systems. In any case what sort of market is there anyway."
>
> (A.M.)

At the time there were systems available for smaller foundries (100 people) and, in his view, the situation has not changed.

Initially the main focus was the computerisation of financial controls, management accounting based on marginal costs, and standard product costing. From this a clear path was established based on the development of a centralised general system. The rationale behind this was based on the view that all of the foundries were in the same type of business and had a fairly similar range of customers. Given this it was decided to develop a uniform management accounting system throughout the foundries division.

M.E. refers to the system as a single system with many facets. This has explicitly informed his methodology since the mid 1970's. The intention has always been to design an integrated system to be used by all the companies but with variations parameterised. For example company names are not built into the programs. Each company has a code number which ensures it operates off the appropriate data-base and prints out the correct company name. If, however, a program cannot be used straight off the shelf then modifications are made to it, but such changes will themselves be systemic. For example, the on-line despatch system was first developed in one company and then transferred to a second who required modifications (consignment stock accounting that includes total weight on delivery notes). This modification was made and then fed back to the original company who now uses the same modified system.

There can be drawbacks to this approach

> "..in certain cases what the companies do can be very specialist and it may not be possible to encompass those very special requirements in detail. At the end of the day, it still has to be a slightly modified general system. And so we fall foul occasionally......There are occasions when we are criticised for providing systems which aren't totally geared to that particular company environment."
>
> (M.E.)

Derby are not yet involved in the production control module, but there are plans to computerise some of the production functions. However, they are not convinced that the transfer of a system from the other foundries would be appropriate.

P.B. Metals also have reservations to the central computing's approach to diffusing a generalised system throughout the group and this has caused some problems.

> "It means that all our systems are more complicated than they need be for any particular company, because the software is written to take account of every possibility in the group, and this does tend to create problems."
>
> (A.P.)

There are a number of advantages from central computing's point of view. On the one hand it simplifies the system design process and on the other it also provides a basis for corporate information gathering. So, for example, the sales and marketing director can get access to consolidated information from all companies on monthly and cumulative sales. It is also possible to monitor customer status in relation to each company and the division as a whole.

Implementation:
Redefining/Restructuring/Clarifying/Routinising

Implementation began in 1974 and has always been tightly controlled from the centre. There are central staff who report to A.M. on the design and implementation of computer systems but the operating companies have no computing specialists at all. This consolidation of expertise at the centre has helped to facilitate the development of uniform systems but it has also caused some difficulties, particularly in tailoring a single system to cope with a diversity of needs. In practice it means there is an ongoing process of negotiation with the operating companies over needs and solutions which have to be largely agreed by all parties. This makes the development process very slow.

The evolution of the system has been piecemeal, not following any formal blueprint. Sometimes the impetus for further development comes from the centre and at other times from the operating companies.

Operation

Currently all the commercial applications are computerised including payrolls, purchase analysis, purchase ledger, sales ledger, sales analysis, nominal ledger, and asset accounting. In addition product costing is a fundamental part of the system. This includes all the basic standard information of weights, standard times of manufacture, the various operations, reject percentages, and customer part numbers. All of this information is held in the 'Master File' and around this revolve other aspects of production monitoring

> "I don't use the term production control, but what it does is enable them to key in customer demand, relate that to casting requirements and, if you like, give them an ability to monitor how they are proceeding. So typically they book the cast information into that system to get scrap recording and so on, and despatch is made and keeps a W.I.P. count so that we can see what is currently available in terms of W.I.P. and to a certain extent where that is on the shop floor relative to what the demand is from the customer for that part over the next, well there is a finite horizon on the system of twenty weeks"
>
> (M.E.)

The system is highly integrated and operates on a common data-base and a single input basis. So from one input indicating the production of a part, and the amount of scrap, W.I.P, stock records, stock values, product history are automatically updated. This means that, at least in theory, the computer should contain an accurate record of what is actually on the shop floor so that customer inquiries can be dealt with quickly. It also makes it possible, for example, to track the scrap record of a product over a twelve month period, or analysis of scrap by cause.

Production data is usually entered on a daily basis at the end of the shift but there are some areas, for instance in the dispatch bay, which operate on 'real time'. The module consists of a terminal on the dispatch bay and as the trucks are loaded instead of making out delivery notes, the details are keyed in. There is automatic validation and, at the end of loading, a delivery note is printed out for the driver. The information is stored and can be used to update the stock record automatically. Then the overnight run will calculate invoices which can then be printed out the next morning. It is also integrated with the ledger.

> "So really you are mixing up your production control and accounting routines from the one input"
>
> (M.E.)

The on-line dispatch bay module provides an interesting example of how the incremental approach to systems development operates in practice. It was originally implemented at the FoundryCo Castings site and has since been put into Derby. FoundryCo was selected simply because of its convenient location to central office "...across the road." According to A.M. it is common practice to design a system and to use one company as a "guinea pig" where any problems can be identified and ironed out and refinements and modifications made. It can then be offered to the other companies as a fully operational system.

At the same time this example provides some insight into the way that the implementation of integrated systems can impact upon an organisation and provide a focus for both change and resistance. It has generated organisational problems in some areas, particularly in that of functional insularity, as the implementation of the system has weakened traditional departmental barriers. This is for two reasons: firstly, there is resistance because people may have to key in data which may be useful to others but is not directly useful to them. Secondly, because the controls on the flow of information across functional boundaries is much greater than on a manual system. So for instance the sales department have to keep up to date on the current situation regarding dispatches etc because they are the first point of contact with customers, and the implication of this is that they are able to view on screen the progress made in other departments. This can result in both friction and change. According to M.E.

> "..because its been put in once somewhere in the organisation it exists for them to view it and so it changes totally the way they have to work"
>
> (M.E.)

Most of the business is high volume standardised products for the automotive market. P.B. for example make the Ford Escort cylinder head at the rate of five hundred every day. They have a single piece of dedicated plant which does not make anything else. Because of this there is limited need for a sophisticated computer system in the production process.

Shop floor scheduling is not seen as being particularly relevant. For example the Derby foundry produces castings on a high volume mass production basis (1,300 tons per week)

> Now we have no monitoring of what's going on the shop floor for the simple reason that it's a waste of time. You are producing and processing your castings so quickly that as long as you know what you start with and what you end up with, what happens in between really is of academic interest because its changing so rapidly."

(B.W.[Production Manager])

The same is true for raw material control which is monitored by "rule of thumb". The site produces 1200 tons each week which, allowing for scrap, translates to around 400 tons of metal melted each day and there is simply not enough room to store it and so there is an arrangement for continuous material delivery with suppliers

> "And, of course, you can visually see what's happening and you do it roughly....there's really no need to have a sophisticated computer dealing with all that. Its a waste of time."
>
> (B.W.)

Work in Progress is also monitored manually

> "You see the castings come down the conveyor belt and we know what we're making and we know the dispatch at the end."
>
> (B.W.)

The situation is different, however on the precision casting side of the business. Sterling Metals specialised in Aerospace and radar etc.. With this type of production there is a much longer time cycle in the process and far greater variety of parts. This makes up to date information on jobs vital. Stirling faced severe problems in controlling this and so they approached the centre for assistance. As a result a system for monitoring production on the shop floor was developed. There are a series of monitoring points (6) and the paper work goes round with the product. There could be up to four weeks between commencing production and despatch. Customer enquiries about current status can be thus answered from screens. This is the only area where this kind of monitoring system is used and it was specifically designed for Sterling Metals.

Scheduling appears to be account driven. Traditionally the foundry sector uses tonnage as a measure of output but FoundryCo uses value because of the diversity between products within the division.

> " ...they know they can handle so many hundred thousand pounds worth of business each month and that's how we load the shop floor because the computer's already got the value through the accounts system, usually customer schedules. Orders are usually scheduled on a weekly basis."
>
> (M.E.)

Capacity planning and M.R.P. are not seen as appropriate to a situation concerning single products which are not machined

There has been a growing demand from the operating companies for production monitoring facilities and the approach is to attempt to tailor an already existing general module to the particular needs of the other companies. In this instance the module designed for Stirling Metals is being diffused throughout the division.

> "...there's now a demand from FoundryCo Castings saying volumes are increasing and we need to know where we are. So we put in, just temporarily the system we designed for the precision foundry and said to them it's not exactly what you want but have a go, try it out and see how it works because we have found that if you go to people and say what do you want, they usually don't know what they want and if they tell you what they want and design it exactly, when its working they come back and say well it isn't exactly what we wanted. That's a common experience."
>
> (M.E.)

The feeling at the centre is that the companies are not able to provide an adequate specification for their requirements. Given that computer expertise exists only at the centre this is hardly surprising. With this lack of familiarity with system design there is a tendency to ask for highly ambitious systems. For example the case of FoundryCo which previously operated entirely on manual systems

> "...we were being pressured by the company. They were saying we want a production control system and we said well you tell us what you want and we'll have a look at it. And nothing comes from out of the company....and eventually we say....you're not getting any where... and they say well this is what we want and they want everything they can think of."
>
> (M.E.)

The central team argue that an important part of their role is to help the companies to clarify just what their needs are

> "..you have to say well do you really know what you're asking for? What are you going to use it for? And you find you've got to tone it down."
>
> (M.E.)

It is not clear, however, to what extent this represents a way of ensuring the integration of the universal generalised system at the expense of the specific requirements of the individual companies.

> "..Then when we suggested to them that we'd got a system at Sterling and why don't you try that out, because I think if you try something out that's simple you will often learn an enormous amount from it and that's what they're doing at the moment. Now we have found very often that if you do that they will modify their thoughts about what they really need."
>
> (M.E.)

this is intended as a basis for system development

> "...in this case we shall probably rewrite a whole new system but its giving them some indication of what a computer can do and the problem is you've got people who have never had anything to do with a computer."
>
> (M.E.)

Within the divisions the impetus for system development is usually a consequence of the inability of manual systems to cope with increased loads, the pressure to reduce staff, and generally "..when they're in trouble" (M.E.) But as noted above impetus may also come from the centre. Currently a new purchasing system is being developed. This will be sent out to the operating companies as a complete package and will be integrated with existing systems.

The only packages that have been bought over the years have been payroll packages apart from that everything else has been developed in house.

Most of the business is large volume production of standardised components and orders are usually schedule based. Although the system was not designed for shop loading it has been extended to include this option.

Changeover to V.M.E.

A the time of writing FoundryCo was in the process of upgrading the operating system from D.M.E. to V.M.E. The idea is to rewrite the systems so that they operate in the same way as before. This appears to have caused quite a headache

> "It's like the birth of a bloody elephant."
>
> (P.Y. [Marketing Director])

The system offers greater facility for expansion and development but entails rewriting all the existing programmes. Apparently there have been some difficulties at head office and there has been an increased turnover of staff. At P.B. there is some dissatisfaction at the current level of progress.

> "I feel that the system today is not as good as it was

twelve months ago when we were on D.M.E."

(A.P.)

This view is shared by Derby where problems of computer capacity are causing problems. The transfer has meant that the operations at Derby are now direct as opposed to batch. The batch was more convenient for them. The turn around is slower with the new system. There appears to be a great deal of competition to get on to the computer but it is very slow as everyone in the division is using it.

> "To me they've got to do something about the size of that computer down there because we cannot get stuff back fast enough now...One of our main problems is we don't get our production figures through fast enough......Now whether V.M.E. has made it better or worse I don't know. All I know is I have to sit waiting. The turn around is not fast enough."

B.W. says that ICL forced the system on them as they refused to continue to support the old one.

At the centre there is a feeling that things are beginning to settle down now but there is still dissatisfaction in the operating companies and it is not seen to be as good as the system it has replaced. A.P.believes that this is because it has not been written in house.

> The old system was ideal, but that apparently was written by our own data processing manager, not I.C.L.. This is I.C.L. software were stuck with. It's not as good"

(A.P.)

Derby came into the FoundryCo group in the late 1960's. Traditionally they have their own way of working which, at least in part, has endured over the years. In particular they tend to work from part numbers as opposed to the product reference numbers used in the rest of the division. Thus with the advent of computerisation and the growth of the generalist system they have found meshing with the system awkward.

> "So we now sort of do both. We have to convert our part numbers into the seven figure product reference numbers. That's all you can work from...so every damn job now has got a product reference and a part number and one of our problems is you run a list of for anybody you'll probably get a product reference list and somebody's got to sit down and write down the side of it what all the flaming part numbers are."
>
> (B.W.)

The Mainframe/Micro Question

The central computing facility services the five foundry companies and charges them for that service. At the beginning of each financial year the centre determines what the individual operating companies will be charged

> "...and that is based on really what we deem to be an equitable split of the total cost of the department. "
>
> (M.E.)

The rapid decrease in the size of the division has inevitably increased the burden of cost that each company has to carry. This has put the central facility in a vulnerable position over the cost of computing facilities and there is a very defensive attitude surrounding the issue of the use of micro-computers.

> "One of the problems being of course, bearing in mind that we are now something like less than half the size we used to be ten to fifteen years ago, we haven't been able to contract the computing costs to that extent, so the cost to the individual companies that are left has inevitably escalated purely and simply because of that. Not because they have used the machine more and more, although that is true...but really the mainframe is still the way to do it. People would argue with that at the moment."

(A.M.)

At the same time the staff levels at the centre have declined and there is much pressure to cut costs. Consequently they are very stretched so it is not always easy to respond to the demands from the companies. Because of this the process of system development, when company driven, is a highly political matter.

> "It is necessary to use as much political guile as one can summon up."
>
> (A.P.)

At Derby there is a feeling that reliance on central computing endangers the company in the face of any future restructuring and the worry was expressed that if they were sold off then there would be a possibility of losing the central computing facility and so this would leave them in a very vulnerable position. There is the possibility of a merger with the Blue Circle group.

> "There would have been no point in developing systems if we were going to be swallowed up by Blue Circle. Heaven knows what would have happened"

Given this situation there appears to be a nervousness in central computing toward the use of micro computers. For example the changeover to V.M.E. has so far taken two years and as noted has caused serious difficulty and yet

> "While all this was going on they really stopped us using or thinking about buying micro computers that we could use to run spreadsheets on or anything like that...it was all frowned upon."
>
> (A.P.)

Technology Networks

The issue of inter firm networks in terms of suppliers and buyers is a fairly simple one in the foundry industry as there is, by and large, a two tier system. The Foundries Division does not subcontract at all. They produce all of what they sell. Consequently there is no extensive diffusion of technologies through firm networks within the sector. The major locus of diffusion stimulus appears to be arising as a result of the internationalisation of the auto industry. The example of the world car is interesting. The Ford Escort for example, is produced in Brazil, U.K., Belgium, Germany, Spain, and North America and although there are some local differences fundamentally it is the same vehicle and this is leading to pressures for standardisation of procedures

> "..I think over time the need to control centrally engineering standards and design and the need to communicate with timing programs that are generated through new model introductions is all going to require us to be interactive with that network. So for us to be a supplier of components on a world car its going to be electronic communication."
>
> (P.Y.)

This issue is in the air but is not seen as an immediate requirement. The major pressure from the large buyers is for quality and S.P.C. is a mandatory requirement. There has also been pressure for CAD/CAM development and FoundryCo has undertaken a "major" study and there is a CAD Master Installation at one of the foundries (P.B. Metals) but there is concern about pay back on such an investment.

The design input for FoundryCo does not concern the major design but involves taking the machined part, as designed, and production engineering it for the process. This is creating pressure for the development of mechanisms for the efficient transfer of data. In 1986

A.R.G. were categorical that their suppliers must have this capability in a short time scale. Since that time the pressure seems to have eased

> "...the pressure is still there but you don't need a whole CAD installation purely to receive electronic messages."
>
> (P.Y.)

The real savings are to be made in CAM. Traditionally the independent foundry industry buys its dies and patterns from independent producers and it is through vertical integration of these activities that the real benefits are to be had. In order to exploit this however it would require an enormous investment as C.N.C machines etc. would need to be installed. "At the moment this possibility is under active consideration." (P.Y.)

There has been an agreement with A.R.G. to experiment at production schedule linkages. The ideas is for their scheduling department to generate their casting requirements with their computer and then that information will be converted into a production schedule for FoundryCo This will then be directed from the centre to the appropriate company. This has moved past the speculation stage and it is intended to start experiments as soon "..as we get V.M.E. under our belt. "

A.M. says that compatibility problems have now largely been sorted out but there are still problems in getting the big customers to agree on a uniform approach.

Derby and JIT

The development of Just-In-Time relationships coupled with computerised order and delivery systems has been very traumatic for Derby. There is a feeling that new practices are being forced on to them by the big customers, and these are not always based on mutual understanding of production problems. Traditionally Derby have worked to schedule but with the advent of computerisation, in the customers, the requirement for greater discipline of Just-in-Time delivery has created difficulties for Derby who resent it.

> "....the order is an open order and you settle a price. You know roughly how many castings they're going to want a month but you actually work to schedule...Customers now have got computerised receiving areas and they know what they should be receiving. Of course in this business you can't send an exact quantity and they're getting a bit stupid now. You can send a load and they'll send 140 back because you've sent too many. The bloody lorry can be on the way back and there's some guy on the phone asking for another two thousand....its that crazy".
>
> (B.W.)

The problem is that they have to over make to allow for scrap and machine stoppages which can be particularly critical and this makes it difficult to produce to strict schedules. The Production department is not used to the new ways of working and they want to shift products as they come of the line.

There is a feeling that the big customers are too inflexible and that this is increasing costs for Derby as they may have to send out lorries which are not fully laden. Nissan practices were cited as particularly problematic.

> "We were going for work with Nissan. I breathed a very, very strong sigh of relief when they told us we've got to supply through a machinist....When they set down what they wanted, my god fathers, you have got to be dead on, absolutely dead on, you will do this, you will do that, you will use our paper work. Very well but what about all the other customers?"
>
> (B.W.)

Meeting new quality standards is also very difficult

> "They want machined castings that go straight on to their production line. ...Ford started it all and now they're all at it."
>
> (B.W.)

Derby also see the computer systems as useful in production monitoring rather than control

> "Its production monitoring, not control. Don't kid yourself your controlling anything."

Conclusion

Clearly FoundryCo is a very diverse group of companies with different operating conditions and different system needs. It is not clear at this point how successful the change over to a new operating system will be and if the centre will be able to resist pressure from the companies for greater systems autonomy.

W.I. Founders and Valley Foundry

These studies were conducted in February 1988

These two cases can be characterised as small but expanding companies who are only recently moving towards computerised systems.

W.I. Founders

Antecedents

W.I. Founders is an independent company producing grey iron castings with an annual turnover of £2.5m. The firm has grown continuously from a work-force of 29 in 1960 to a current one of 110. In terms of labour force profile this breaks down to 60% unskilled, 25% semi-skilled and 15% craft-trained employees who are mainly concerned with machine maintenance. This dependence on low skill levels and high labour intensity is a common story in the British foundry sector and there is a recognition of the need to address this by improving levels of investment in training and technology. A new production process that cuts out the need for machining has recently been installed and other developments in electric melting and improvements in the sanding process are planned in the short term with machining remaining a long term objective.

The main business consists of core-making, mould-making, casting, grind and finish, and surface coating. Products are then passed on to customers for final machining and assembly.

The firm was established in 1941 but in recent years there has been a radical shift in terms of product strategy, process technology and management structure. It has shifted from a dependence on builders castings to a more general engineering market and has diversified its customer base to improve its vulnerability from an over-reliance on too few customers. The current policy is not to allow one customer to take more than 20% of their business. The fact that they do little business with the automotive industry makes this possible. Three customers take 60% and the remaining 40% of business is spread amongst smaller customers.

The managing director identified the major problem facing the firm as the tension between an ever increasing demand for quality from the large customers. For example there is very strong pressure to achieve BS 5750. And yet the customers continue with the tradition of using price as the major indicator of competitiveness. W.I. do not make an end-product but produces castings for finishing as components of their customers products.

Initiation: Agenda Setting/Matching

Five years earlier there were no computers at all in the organisation and then one desk top micro with dual floppies was bought to handle accounts and two years later a hard-disc based system was purchased for production control which is currently the focus of further development and updating. However the two applications have developed in isolation and there is now a growing recognition of the need for closer integration of functions.

The feeling is that the two systems have, by and large, worked fairly well. Accounts has been less problematic as is to be expected given the largely standard nature of the process and available packages. Production control has improved order and delivery times but there are problems in the way it is used, resulting from the low skill levels in the work-force, compounded by a lack of adequate training. In particular there are problems over achieving accurate and up to date data. The view has been expressed that the existing work force would "..freeze if you put a computer print out in front of them." There is no in-house computer expertise and there have been difficulties in recruiting suitable personnel to provide it.

There have been attempts at training but they have been limited and marginal. Sessions have been arranged totalling 8 hours per year for each employee and twenty hours for management but staff have complained that they are too overworked to digest the information. Despite these efforts only eight out of a planned twenty staff actually use the production control system.

There are talks with a supplier of CAPM systems to install an integrated computer system. The main reason for this is to help cope with the increasing volume of business and to aid the delegation of decision-making on production and deliveries. The managing director talks of production supervisors "running around chasing their tails" and being overwhelmed with unnecessary paperwork and identifies a key problem as the loss of control at every level

> "At one time I could have told you everything that was going on, even what time a particular bloke went to the lavatory...now nobody knows what is going on. We're getting to the size where some areas get lost."

The implementation of a computer system was seen as the key to restoring control at every level and integrating functions more closely.

However there are problems and these, at root, go back to the low level of skills and training in the work force. Given that the existing system is not being fully utilised the M.D. finds it hard to justify the extra cost and the key is seen as the recruitment of a production controller who would have experience of both foundry operations and computer operation. To date they have not been successful in finding anyone and there is a belief that salary levels simply would not be sufficient to attract a suitable controller.

Nevertheless further development is seen as essential as the company has grown to a critical point

> "We're at the edge of the precipice, where to survive we might have to take on ten ancillary staff to administer the foundry.:"

and a computer system is seen as vital to free management from day to day involvement and to avoid escalating admin costs.

Valley Foundry

Antecedents/Corporate Information

Valley Foundry (Newcastle-Under-Lyme) is also an independent family business producing grey iron castings for the engineering industry. It has a work-force of 90. Current output is 75 to 80 tones of castings each week and the annual turnover is around £3m. The business dates back to 1946 and continuous expansion led to a move to a new site in 1976 and the old site was retained as an overflow patterns store. Practically all the moulding, both conventional and boxless, is done in furan sand with the exception of shell moulded cores. Since 1976 there has been heavy investment in new process equipment. It usually works to customers' patterns but also produced its own.

Initiation: Agenda Setting/Matching

Commercial applications had been computerised for some time and, in the face of expanding business and an increasing work-force, a review of its management structure was underway and a CAPM system was being introduced. The company has a customer base of over 200 and a single inquiry over the state of an order could take up to ten minutes to retrieve the relevant data and so the computer system is seen as a way of reducing this time by making information available at "the touch of a button". (J. L. : Managing Director).

The reason given for the changes, both organisational and the implementation of a computer system, was to improve the flow of information and control. The new production controller was seen as a key figure here and would be responsible for all inputs with all the other screens used for information extraction only. Shop floor operatives would continue to record information manually but now they would pass it on to the production controller who would enter it into the computer. The reason for this method was that the M.D. felt that the system was going to be the company's "lifeline" and it could be undermined by the entry of inaccurate information. Given the central importance of the Production Controller great care was taking in recruiting the appropriate individual and the suppliers of the system played an important role in this.

Although Valley usually work from patterns produced by their customers they do have the facilities to make their own.

There are two major reasons for the implementation of a computer system. Firstly, the loss of management control in the face of the expansion of business. Previously the Managing director says he could manage the business from memory and experience but this was no longer possible and a computer system was seen as essential to cope with the increased load. The expansion of business had meant that some activities, like marketing, were being neglected in the scramble to maintain control which meant that managers were spending more and more time on production control and progress chasing. The computer was intended to produce enough slack to enable managers to focus more energy on external rather than internal activities.

Secondly, quality standards in the foundry industry had been notoriously variable and now there was growing pressure from the customers to improve quality standards. Valley say this is something they were doing anyway but now there is a new urgency. The company is in the process of implementing BS 5750 and computerisation was seen as an important element in assisting with this.

Implementation:
Redefining/Restructuring/Clarifying/Routinising

Valley had commissioned a firm of consultants (DEWTEC) to install both hardware and software components of the system. At the time the computer system was not up and running but would eventually consist of a computer and 10-15 screens. Currently there are four people using computers and this is to be gradually increased over the next twelve months as new people were hired. Currently the main activity is the transfer of existing manual data onto the production control computer. Two temporary operatives had been taken on to do this.

According to the managing director the computer system was not seen as a solution to their problems in itself and the main thrust was in the direction of organisational change, producing a more formal system than had previously existed, which would be assisted by improved flow of information achieved through computerisation.

There were no plans for shop floor data input. Operatives would continue to generate information manually which would then be passed to a production controller who would input the data into the system. There was an attempt to ensure the integrity of the data as the production controller would act as a buffer between the manual and the computer system. Clearly the production controller was to play a key role and they had 'poached' someone with previous experience from another foundry.

Pressure from customers had made scheduling an important aspect of production but there were no plans to computerise this. Instead the computer system, together with the organisational changes were intended to make the organisation more responsive.

CHAPTER 6

Discussion of Case Studies and Rogers' Model

Initiation: Agenda Setting, Matching, Decision

As noted above Rogers model can be seen as one of adoption and the first part of his two stage model outlines the process leading up to the adoption decision. The agenda-setting stage concerns "all of the information-gathering, conceptualising, and planning for the adoption of an innovation, leading up to the decision to adopt" (1983: 363) The first stage in this is agenda setting in which general organisational problems, which may create a perceived need for an innovation, are defined and a 'performance gap' identified and then the environment is searched for innovations of potential value to the organisation. Rogers' adoption of a processual approach to adoption and implementation is useful and his identification of stages is helpful in analysing complex situations and processes but overall his account is too simplistic to capture the complexity of real processes.

A major restraint on the model is that, as we have seen his early ideas on innovation and diffusion were rooted in communication theory and modernisation theory, and in the process of trying to apply them into organisational contexts the highly rationalistic character of these traditions has been translated into his treatment of organisations. Often, in the course of his work, this emphasis is implicit rather than explicit and this, at least in part, is due to the fact that his style of writing and his treatment of concepts tends to be broad in scope but low in detail. It is necessary, therefore to draw on a broader literature on organisational processes in order to locate Rogers ideas in a more developed theoretical position.

It was noted above that Rogers' model is best seen as a model of adoption and in particular the decision processes that surround this. Rogers' thinking, then, is indicative of the highly rationalistic view of decision making that has been the centre of a great deal of discussion. Rogers model can be seen as a variant of the classical rational choice model (Richardson and Jordan, 1979). This model includes the identification of problems, the clarification of objectives, the identification of possible alternative solutions, and finally the choice of a course of action with consequences most closely matching identified goals. Rogers notes, in passing, that the process can be either problem-initiated or innovation initiated. Clearly, here he is drawing on March's (1981) notion of solutions in search of problems, and the idea that organisations are continually scanning the environment, in an opportunistic way, for ideas that might be useful.

Do the case studies lend support for this view of the decision process? The first point to make is that there is a great deal of diversity. The process at ElectroCo, at least on the surface, appears to fit with such a scheme. First, clear problems were identified - technical inefficiency and economic savings. Objectives were set and the environment scanned for the best solution. The preferred option was selected on the basis of clearly identified criteria that were applied to each of the potential suppliers before a decision was taken. FoundryCo, on the other hand would appear closer of Lindblom's (1959) notion of disjointed incrementalism, making small modifications to a well worn system without moving beyond well established routines.

In Rogers model the environment is dealt with by means of the concepts 'knowledge' and 'external accountablity'. Knowledge is defined by

> "partly the characteristics of the personnel.....and partly by the existence of defined search processes"
>
> (Rogers and Rogers, 1976)

External accountability refers to the stable set of networks in which actors may be involved.

In all cases the relationship with the environment is not so straightforward that it can be considered a stable externality to be scanned. The case studies show a variety of different relationships with the environment, and in particular the degree to which they were dependent, or not, on suppliers for making sense of CAPM. I will return to this issue later but it is important to realise that the 'environment' is not passive but encompasses elements that play an active role in the innovation process, as in the case of suppliers, or in spurring the search for innovation, as in the case of corporate reorganisation and cost cutting.

Even in the case of ElectroCo the rational account exaggerates the degree to which the process is part of a stable ongoing set of organisational processes. ElectroCo, like all the other cases, were undergoing a period of great change which could be seen to disrupt organisational processes so that scanning was not routine opportunism but stimulated by external influences - the creation of decentralised business centres and the need to curtail costs for which the operating units were now completely responsible. The same can be said of BritCo which had recently undergone restructuring and PlastiCo whose ownership had recently changed and new personnel had been introduced. W.I. and Valley were not only experiencing pressure stemming from an increase in business but were also under a great deal of pressure from customers to implement quality procedures (BS5750). In each of these cases it could be argued that rather than routinely looking for possible innovations to solve ongoing organisational problems the 'performance gap' was forced upon them and in each case the need for cost cutting following restructuring was a key issue.

The rationalist approach has a number of other limitations and other approaches have been developed to address these short-comings. Allison (1971), has suggested two other models - the organisational process model, and the political bargaining model. Allison stresses that these models are not competing accounts of 'reality' but simply different ways of throwing light upon complex processes, each of which throws different issues into relief. Thus the point is not to establish the epistemological superiority of one to the other but to identify strengths and weaknesses, and use each as a way of exploring data from different angles (Morgan, 1986).

To a great extent the use of the idea of the performance gap locks Rogers model into the neoclassical notion of 'economic man' in search of maximisation in a free market of unlimited information,

> "..a performance gap creates a search for innovations"
>
> (Rogers and Rogers, 1976)

But organisational process models dismiss this as too simplistic and instead introduces the idea of 'administrative man' (Simon, 1947) who is characterised by uncertainty, in possession of incomplete information, operating with a rationality that is clearly bounded, who simplifies the world to make it manageable, and is content with satisficing, accepting that which is just good enough as opposed to the optimal. We will see later how the development of strategies for dealing with uncertainty plays a key part in the adoption and implementation process.

The organisational process model is critical of the classical rational model on a number of grounds. Firstly, it is based on a behaviourist socio-psychological model (Reed, 1985) that emphasises individual rational behaviour which is then transposed to organisations as though they are super individuals with extended information processing capacity (McGrew and Wilson, 1982). This is just what Rogers has done in the application of his earlier model to organisations. For example he argues that

> "...many of these characteristics [innovative organisations] were the equivalent of the characteristics of innovative individuals. For example, larger sized organisations are more innovative, just as individuals are with larger incomes and higher economic status."
>
> (1983: 356)

This is a serious shortcoming that Rogers has not been able to fully address. The notions of 'collective' and 'authority' decisions which are used as an attempt to apply the earlier individual, decision based, rationality to organisations, discussed earlier, are too simplistic to capture organisational processes. In each of the cases the decision process was complex and the outcome of the interplay between a number of different actors with different, sometimes conflicting views and opinions. For example in the case of PlastiCo the final decision was a product of the interplay between the firm of consultants, the managing director, the finance director, the suppliers of software, and head office. The outcome was not a product of the sum of all the information they held but of the interplay, sometimes conflicting, between them.

Secondly, it is impossible to have comprehensive information available in order to make the optimum choice. This is particularly true in the case of complex computer technologies that are poorly understood by potential users, and given this rationalities are bounded, and decision making arises out of pre-existing routines and procedures designed to reduce uncertainty and place limits on the search process. Further, organisations often continue to be moulded by their original templates (Child et. al., 1987), This clearly illustrated in the case of BritCo whose entrenched routines and practices were personified by the production director and this placed enormous restrictions on the final choice as it had to conform with existing practice and to be "idiot proof" so that it could be operated by group of individuals who were resistant to computerisation. The complexity of the computer system is simplified by forcing it into a familiar template that already exists in the form of the manual system.

Thirdly, concepts like Rogers's key one of 'collective innovation decisions' is inadequate to the task of capturing the complexity of organisational processes. In organisations it is very difficult to arrive at a single set of goals or even preferences as the decision process is fragmented and disjointed amongst many different individuals, involving elements of interfunctional competition, individuals pursuing their own interests in terms of security or personal advancement. Success in the field of computer system implementation was seen by a number of interviewees to be an important aspect of career advancement.

Fourthly, rationalist approaches have been described as utopian (Smith and May, 1982) as they do not approximate actual processes but represent a 'planners dream'. It tends to confuse the explanatory with the descriptive and thus refers to the way things *ought* to be and not the way they *are*. Rogers (1983: 191-193) maintains that the stages he describes occur in a chronologically logical fashion but the evidence from the case studies does not support this and, for most the whole process was far 'messier' and less rationalistic. In reality such processes are characterised by important but unforeseen and unintended consequences that make it very difficult to keep all the 'stages' separate. On the other hand the researcher often has to rely on reconstructed accounts of processes that have become simplified, 'typified' (Schutz, 1972) and rationalised over time. This is a difficult issue for the researcher to pick out as it requires extracting rationalisations, justifications and legitimations from actual processes. For example in the PlastiCo case the consultants were able to produce a clear, rational staged account of the whole decision and implementation process but this account, which figured in their original sales pitch, was clearly not a reflection of the processes that occurred which were much messier and disorganised. At a board meeting, for example, the accounts director at PlastiCo explicitly accused the consultants of not adhering to their own methodology.

Incidents of this kind are indicative of the political nature of organisational processes and the political bargaining model highlights other issues. Rational calculation and organisational criteria are used to define, justify and legitimate decisions as part of a bargaining process, the outcome of which is determined politically - not by force of argument. The key issues are those of informal structures of power, the availability of resources and the negotiating skill of participants. Thus assertions like "attitude" is the most important element in the introduction of CAPM (Monniot et. al., 1987) is far too simplistic and also open to the criticism of transferring attributes of individuals wholesale to organisations. There is clear evidence that commitment from the top is of great importance (White, 1986; Krupp, 1986)) and the case studies would tend to support this, but the notion of 'attitude' whether led at board level or department level, greatly simplifies the nature of the interaction between different parts of the organisation and the degree to which 'attitude' is fragmented around an organisation. This is the case in ElectroCo, FoundryCo, BritCo and PlastiCo. Deans (1987) has argued that the decision process in organisations is characterised by an individual or set of individuals who are highly committed to a course of innovation and who set about justifying this commitment to those who have the final say. The process of 'gaining approval' involves three components, strategic, social and political. The strategic component is aimed to justify the innovation on the grounds of benefits in terms of improved financial performance and/or market performance. The social component refers to the demonstrating of commitment and credibility so that final decisions are often based not on rational calculation, but on an individual's track record. The political component refers to the winning of the support of the upper levels and other key actors and creating solidarity amongst different groups or individuals.

In the case of ElectroCo it is difficult to extract the actual process from its public presentation. It is important to realise that in order to secure the changes sought, largely in search of cost savings, E.L. had to convince his divisional board of the relative advantage. To do this he had produced prepared presentations that rationalised the decision, complete with diagrams of planned stages of adoption and implementation. At the heart of this was the political problem convincing his superiors of the wisdom of ditching corporate computing in favour of in-house systems.

> "As you can imagine we bought time from the Group computing at Shirley and there was some political problems going on, and we wanted to come away. We were talking big money, three quarters of a million pounds, that sort of money."
>
> (E.L.)

Deans (1987) argues that 'champions' of innovations often link the proposed changes to emerging corporate ideologies in order to win support and in the case of ElectroCo E.L. clearly linked the development of micro systems to the new corporate commitment to decentralisation. This was an avenue that was not open to P.B. Metals at FoundryCo. Further, E.L. had prepared his presentations prior to the actual process to win board room support for his proposals and the scheme he had used was based on work by an academic at (Colin New) who's work he was introduced to while studying for an MBA at Warwick University. But importantly these are the same presentational materials that E.L. uses to *describe* the actual process as it occurred. Clearly there is a tension here between what is and what ought to be that is difficult to resolve.

Rogers elevates key individuals to important roles in the innovation process, for example he uses the concepts of 'opinion leaders' and 'change agents'. However, individuals, groups and organisations have self-defined interests to protect and any formal rationality is subjected to these. Although the literature on innovation is full of 'success' stories it is by no means clear that embarking on a course of change is necessarily beneficial to an individual's career and indeed may prove hazardous (Brimm, 1988). This means that the decision space is complicated by competing problems and competing preferred solutions in an attempt by each participant to ensure that any final decision is not damaging to their interests. This point is well illustrated in the cases of BritCo where the production department was wary of both increased functional integration and increased surveillance from the centre. At FoundryCo there were tensions between central computing and the companies. Thus the 'rationality' of change agents may be very different to the rational role ascribed to them by Rogers.

When faced with a decision problem, participants focus upon those aspects of the problem that they define as affecting their parochial interests. In consequence, rather than a single strategic problem requiring a solution, there are a multitude of interrelated issues competing for the decision makers attention. At BritCo the production director's main preoccupation was not only meeting monthly output targets but also being sure that he was going to be able to, and he was resistant to anything that might possibly interfere with either of these interests. Even though he felt the production department was working under extreme pressure and the manual system of monitoring was creaking at the seams he was extremely reluctant to depart from it in favour of something less familiar to him and this exerted an important influence over the decision process, the implementation process and the operation of the system.

At FoundryCo the system had been developed over a long period of time and a fairly clear set of procedures and practices for system development had been established. However, as with ElectroCo, rationalisation over a period of years had resulted in a smaller organisation with fewer operating companies whose share of the cost of the central facility had increased. Other foundries, like Duport Harper, had already got rid of their central facility which was bought out by management and operated as a private business selling services to the operating companies. Staff at the centre were very aware of their vulnerability and actively discouraged the companies from developing alternative system solutions. This led to some particularly acute tension at the P.B. plant where there was a wish to introduce micro systems but this was vetoed by the centre even as a stop gap for running accounting spreadsheets during the considerable disruption caused by the upgrading of the operating system.

A further point of interest is the notion of 'non-decisions' (Parry and Morriss, 1974) or decisions that were never taken, or possibilities that never made it on to the agenda in the first place. Many MIS departments are reluctant to relax their control over systems development (Beheshtian and Van Wert, 1987) and this appears to be the case at FoundryCo. For example, the centre at FoundryCo had a commitment to maintaining and developing the mainframe system and this was the policy they pursued even though there was evidence from the companies that the new system worked less well than the old. The decision for the operating companies to switch to micro systems was, in effect, kept off the agenda. This was possible because central computing had been developed in the accounting functions first and the finance director had maintained his control and was able to represent central computing at high level forums.

Lindblom (1959) has produced a more extreme critique of the classical rational model, although Richardson and Jordon (1982) argue that the difference between his view and Simon's is the attitude they adopt to the practices they observe. For Lindblom decision making is a much more pragmatic affair than is usually presented. Decision makers tend to select between a few alternatives that are presented to them and they do not dwell on values and goals. The normal process is to start from a problem and then to consider a manageable range of alternative solutions. A consequence of this is that decisions tend to gravitate much more towards the very routine and decision innovations tend to be incremental extensions of past practice and it is common to return to the problem later to make further modifications or extensions in the light of changing circumstances. Decisions will only receive the support they need to prevail if a consensus is achieved and for this reason 'rational' decisions, that might require change or reorientation, are often avoided in favour of those that reinforce the status-quo. This means that only minor changes make their way on to the agenda.

This view would appear to apply to the cases of both FoundryCo and BritCo. In the former, identified problems of production control and management information were viewed only in terms of incremental change to the existing system which was never called into question by the centre. In the latter case, the starting point was clearly defined in terms of the established practices and procedures and decisions around the adoption of the systems were clearly dependent upon replicating them in the new system. Watson was clear that it was only by proceeding in this way that he would be able to take the production team with him.

For Lindblom rational models, even bounded rational ones, are too rigid to capture the nature of decision processes. They make too sharp a distinction between means and ends, and facts and values. He argues that means and ends are often chosen simultaneously, means often precede ends, ends become means over time, and values may rationalise rather than determine decisions. Ends, which usually represent the problem to be solved (the performance gap) are constantly subject to redefinition in the light of the means available to solve them.

Means and ends appear particularly mixed up at PlastiCo. The computer system was presented as a means to generating the management information necessary to achieve the business objectives identified at the outset but it is by no means clear if this is a rational justification. The consultants were general management and had no previous experience of systems adoption and implementation and there was obviously suspicion amongst staff at PlastiCo that they were being used as guinea pigs for the consultants to develop an expertise in this expanding market, something which was a growing trend at this time (Madden, 1988; Mehta, 1988). What are the implications of this for relationships of means and ends? The computer system was presented as a means to a particular end - achieving identified business objectives at PlastiCo, but, at the same time, appears to have been a means to a quite different set of ends for the consultants - the consolidation of their own expertise in this area.

The disjointed incrementalist model is not itself without problems. It has been criticised for being conservative in that it reinforces inertia and denies the possibility of radical change and also it provides no way of identifying 'good' decisions beyond the prevailing consensus and it would be difficult to fit all organisations, e.g. ElectroCo and PlastiCo, into this mould. Like rational models this view appears wedded to a view of organisations as stable entities in stable environments and is not well placed to deal with the shock to the system experienced by organisations undergoing periods of instability and change. It is difficult to change attitudes but the kind of rationalisation of labour that was taking place at ElectroCo, PlastiCo and BritCo has a way of encouraging flexibility.

Rational models then, have been criticised for presenting a poor description of the way in which organisations, in general operate, and of the way decisions are taken in particular. As noted above, such views have been criticised for representing an ideal situation as opposed to a real one. However, even the idea that rational models represent the way the decision process *should* work has been called into question. For example, Morgan (1986) cites Norman Wiener's (1961) work on cybernetics which throws into doubt rationalist ideas about the learning process. Organisations can be seen to work not by continually taking rational decisions but by invoking 'negative feedback' to counter deviation from a set course, rather in the way that a ship's rudder might. So, as with the bounded rationality model, organisations are characterised by entrenched practices and procedures that limit uncertainty, but as well as this there are also routines that act as responses to perceived deviation from a set course. The point is, that this is fine as long as the organisation is on the correct course but if, perhaps as a result of a change in the environment, the course is the wrong one then such procedures may act to keep the organisation performing in an inappropriate way in the changed context. The procedures of negative feedback may result in 'rational' means being harnessed in pursuit of 'irrational' ends.

If this is the case the key issue is not whether rational processes of behaviour exist but whether mechanisms exist that can enable them to be re-evaluated in the context of a changed situation. This insight has led to the identification of two types of organisational learning: single loop and double loop (Argyris and Schon, 1981). Single loop learning is associated with rational decision models and is characterised by behaviours like scanning the environment, setting objectives and monitoring performance in relation to those objectives. Double loop learning requires actors to stand back from established routines, practices and procedures and to take a critical stance to see if those procedures are appropriate. This would appear to be the case at ElectroCo where the existing way of proceeding was challenged and changed. However the outcomes of such a process are always in doubt (Brimm, 1988) and so can be a risky process which makes it attractive for individuals to live with the devil they know, a stance which characterised that of the production department at BritCo. Further, there is always a danger, having taken a critical stance and opting for radical change, to fall into another single loop that is inappropriate and this may have occurred at PlastiCo where the management commitment to the new computer system was great but ultimately misplaced.

However most organisations, particularly the classical bureaucratic kind, tend to obstruct this possibility for a number of reasons. Firstly, bureaucratic structures tend to impose fragmented structures of thought as individuals awareness is bounded by narrow hierarchical and functional concerns (BritCo and FoundryCo). Secondly, bureaucratic accountability leads to defensiveness at every level as individuals are implicitly encouraged, by mechanisms of censure and approval, to place the maintenance of the bureaucracy before the goals it was designed to achieve. Thirdly, in such contexts there is often a disparity between what people say and what they do. Schon (in Morgan, 1986), has referred to this as the distinction between *espoused theory* and *theory in use*. The problem with this is that actors develop their own discourse for rationalising situations and this results in the establishment of 'mind sets', or ways of thinking, that are difficult to challenge.

The data from the case studies would suggest that most of them were characterised by single loop learning. FoundryCo, in particular was stuck to an entrenched way of doing things that had worked well in the past but was coming under increasing pressure in terms of both efficiency and cost. ElectroCo, on the other hand, would seem to be a case of double loop learning the traditional way of proceeding was challenged and overturned in favour of a new approach.

In summary Rogers model is a useful device for ordering complex empirical data into categories that enable us to make sense of it. However, it is overly rationalistic and we should be careful not to conflate the categories that we use to organise realitywith 'real' processes (Newton-Smith, 1981; Sayer. 1984). Clearly individuals use rational models to organise their activities, notable in the cases of PlastiCo and ElectroCo, but the outcomes are the products of complex processes deriving from individual intentions, organisational and political processes.

Implementation

It will be recalled that Rogers' account of the implementation process entails a number of discrete stages of redefining and restructuring, possibly including reinvention, clarifying, and finally routinisation. The strength of his model is the degree to which it conceptualises the process as a negotiated one in which changes to both the organisation and the innovation are an integral part.

The process of implementation in the case studies was characterised by a number of dimensions that concern the particular methodologies employed. First, the size and complexity of the system adopted.

Monniot et. al. (1987) have argued that the learning curve in relation to the implementation of CAPM systems needs to be measured in years and not months and they present a model in which adoptors pass through a succession of stages from no CAPM to a completely integrated manufacturing system and suggests that movement should be incremental consolidating one stage before moving to the next. This view is in keeping with Rogers' account of adoption and implementation and particularly his concept of 'trialability'. However, the evidence from the case studies would suggest that this view is oversimplified and that some organisations are better able to cope with 'large jumps' than others, and further even at the lower stages companies still experience difficulty not only for technical reasons (e.g. accurate data input) but for organisational reasons. This leads on to the second dimension which concerns, not just previous levels of implementation of CAPM but the whole range of organisational knowledge that exists at the time of implementation and this includes both technical and organisational knowledge. These two important dimensions are crucial in shaping the processes surrounding implementation including: dealing with uncertainty; relations with suppliers; level of commitment from above; the interaction between the existing (manual) system and the (new) computerised system; training and education, the question of ownership, the importance of small successes, relations between operating companies and the centre.

Characterisation of methodologies

The case studies are characterised by a wide diversity of starting points, implementation methodologies and implementation experiences. ElectroCo developed a blue print for selection and implementation and evaluation of a comprehensive system and followed it through in a systematic way to a successful conclusion. PlastiCo, on the other hand also began with a clear idea of what they wanted but proved unable to translate this into a successful implementation of the computer system. BritCo set its sights lower than these two and followed a more restrained and cautious approach to the adoption and implementation process. In so doing they managed to avoid the complete disaster experienced by PlastiCo but nevertheless have experienced some serious problems in system operation and development. FoundryCo followed the tram lines they had been in since the mid 1970's and continued with their centrally driven incremental development even though this was leading to strained relations with some of the operating companies.

What do the case studies tell us about successful strategies in the implementation of CAPM systems? The cases show a variety of approaches and a variety of outcomes. If we compare PlastiCo and ElectroCo we see in both cases the design of a clear and careful implementation strategy and yet one case stands out as a clear success and the other as a disastrous failure in terms of computerisation. Clearly methodology is necessary but not sufficient as there may well be different methodologies that may prove successful (McLoughlin et. al., 1985; Burker, 1988) methodologies tend to overemphasise linear relations at the expense of complex contexualisation. For example, Braun (1985) argues that the key to the process is to be found in the nature of complex 'constellations'. By this he means that in complex situations outcomes are subject to the existence of a constellation of various circumstances. To investigate the outcomes at the different cases we need to examine the size and complexity of the various systems, the level of organisational knowledge, relations with suppliers, the kinds of implementation strategies adopted.

Size and complexity of system

The actual systems adopted and implemented vary considerably from BritCo who went for an off-the self system with just a few basic modules that could later be added to ElectroCo and PlastiCo who both went for complex bespoke systems that included a wide variety of integrated CAPM functions. Quite clearly this decision is a key factor in the unfolding processes and it is clear that while ElectroCo managed to cope with this level of complexity, PlastiCo were over ambitious. BritCo tried to keep things simple and still experienced difficulties at every stage and were finally left with an inflexible system that was going to be difficult, if at all possible, to expand. FoundryCo were concerned to develop piecemeal an existing mainframe system to include a number of CAPM functions.

Clearly starting points are of fundamental importance to levels of success and failure. Samek (1986) has argued that the complexity of the technology coupled to the degree of change it produces is the central issue in the outcome of a system implementation. Starting points include the level of prior systems development, the existence of personnel experienced in system implementation and operation, and linked to this the existence of stocks of knowledge at both an individual and organisational level.

Organisational knowledge

In the case of ElectroCo there is a history of system development at both corporate and operational level. The organisation had been through similar episodes on many occasions over the years and had built up considerable understanding of the processes of both adoption and implementation. The key figure in the implementation, E.L., had been involved in system implementation at other organisations, some of which were successful and some of which were not, and had developed a clear understanding of what to expect. He had an awareness of the problems he was likely to face at every point, from the selection of hardware and software, the need to structure relationships with suppliers and the mistakes by others and how to avoid them. Added to this experience E.L. was engaged in a continuous process of maintaining and upgrading his knowledge base, as is demonstrated by his links with higher education.

We might consider it important then, that the innovation 'champion', be equipped with the appropriate knowledge and experience to guide the process to a successful conclusion. However the existence of stocks of knowledge at this individual level may be necessary, but cannot be seen as sufficient for a successful outcome. For example, there are parallels between E.L. and Bury who also had been involved in previous processes of system implementation and indeed held a doctorate in 'Total Technology' from the University of Aston. Bary Took (PlastiCo) was also experienced and yet they were not able to translate this into a successful outcome. Clearly the reasons for this are complex and will be considered in detail in the course of this chapter. By focusing on the attributes and activities of individual actors, champions, or in Rogers terminology 'change agents' we must not lose sight of the fact that knowledge needs to be understood at both an individual and organisational level. One thing that sets ElectroCo EMS apart from the other cases is the degree to which there was a familiarity with and an acceptance of benefits of computer technology at every level in the organisation. This is important for a number of reasons. Perhaps of most importance for the implementation process is the fact that it tends to reduce organisational resistance to the implementation process.

> "...beginning that it was electronics, and as people were brought in they were instilled in the early stages, they were trained that computerised systems were good. And we've got girls on the shop-floor now and they run the actual apparatus on all the different lines, modules, cells, sections within the shop-floor....Now at other factories I've been to you would never get an operator to touch a keyboard to a computer. Its just part of their nature. They were there to put the bits together."
>
> (S.G.: ElectroCo)

This stands in stark contrast to the situation at the other cases. At BritCo Watson had brought with him a commitment to the benefits of computerisation and some experience of adoption and implementation, but he was virtually alone in this. He was surprised when he joined BritCo at the low level of computer awareness: there was no previous tradition of computing, even the accounting functions operated on manual systems

> "I'd come from a large group which had computers since the seventies...we'd gone through the whole process of implementing a production control system....I really could see the potential of a computerised system...having worked with manual systems [at BritCo] for two years, anything was better than nothing."
>
> (M.W.: BritCo)

This meant that there was not only a lack of technical expertise which increased the need for a good programme of training but also that there was enormous resistance to computerisation to overcome at very level in the organisation from the top to the bottom. It was this restraint that moulded Watson's view of what was possible and influenced every decision in the adoption and implementation process. Watson says that his awareness of this problem actually structured the implementation process as it was essential to find a way to "..provide space for people to grow.' and at the same time to avoid difficult problems of system design that they were not in a position to solve. Thus the decision to go for an off-the-shelf system in incremental stages.

The situation at PlastiCo is more complex. A lack of in-house systems experience can force over-reliance on suppliers (Graham and Rosenthal: 1986) and this appears to be what happened at PlastiCo. Both Bury and Took added to the organisations stock of knowledge but beyond them there was very little other experience and bringing the relevant knowledge and experience into the organisation is a key feature, first via the hiring of consultants and later, following the realisation of failure by hiring a systems manager to take control of system development. The problem with the consultants is that they were new to systems development and implementation, and rather than adding to the stock of knowledge they appear to have been engaged in their own learning process, and the result was to fragment the knowledge base by creating organisational friction at a political level: basically between the new M.D. who supported the consultants and the finance director who did not. With the departure of the finance director and the consultants PlastiCo were left to pick up the pieces and hence the hiring of a systems manager with a brief to salvage the situation or start again.

At FoundryCo there was clearly considerable knowledge and expertise but it was concentrated at the centre which meant that the operating companies were not in a position to develop their own competences. Whereas in ElectroCo the tension between central functions and the operating companies was solved by EMS taking control of its own systems development. The companies at FoundryCo were less well placed to embark on such a radical path and were so tied into the centrally driven incrementalism that characterised that company.

Ownership

A recurring theme in the literature on implementation is that of ownership and there is much evidence to suggest that systems that are imposed on organisations are less likely to succeed and reach routinisation. However the situation is more complex than this. If we take the case of PlastiCo the M.D. says the system was not imposed upon them from above and shows a clear awareness of the problems associated with such impositions. His view appears to be, that as the decision to adopt was made internally and only sanctioned from above that this amounts to ownership. However this view was not shared at every level in the organisation and this may highlight a problem with the use of consultants in system implementation. Because the consultants were inexperienced in this field they were sensitive about admitting to problems and were reluctant to 'hand over' modules until they were fully operative. The experience for PlastiCo operatives was one of being handed over modules, whose design they had not been consulted on and then, on many occasions, watching them fail. This, of course meant increased work load for them when they were already hard pressed and the system came to be seen as belonging to the consultants, while they had no part in its design or development and it is not surprising that they eventually lost faith in it and reverted to their own manual systems. Even at board level participation was curtailed. The finance director was briefed to work with the consultants so that there would be on-site expertise after they left, but his experience paralleled that of operatives and the consultants created barriers to his participation while there were problems to be solved. In this sense the system may not have been imposed from above but it was, by default, imposed by the consultants.

At BritCo the issue of ownership took on a different character and we can see that imposition is not the only issue associated with ownership. The importance of user involvement at every stage is also prime. Here again the system was not imposed from above but it was strongly associated with one person, Mike Watson, who had been the moving force behind the adoption. The production department was not closely involved in the developments and given the resistance he encountered and the general lack of knowledge and expertise when things did go wrong it was seen as his problem or at least as a problem with 'his' system. Gradually he attempted to overcome this problem by drawing people into the process via the mechanism of setting up lines of responsibility for problem solving in order to nurture a sense of ownership.

At ElectroCo this was identified as a key issue at the outset and the adoption/implementation was designed to draw people into a close involvement. This was a major rationale behind the setting up of the three working parties. The suppliers, prior to tender, were invited to meetings with the working groups so that discussions on nomenclature for example, were not theoretical but grounded in the operating experience of those who would use the system.

At FoundryCo the approach could be described as a top down approach and there was a clear sense in the operating companies that the system was not of their choosing but one they were obliged to use and which was designed not specifically for them but simply modified for their use. The centre stressed that developments were user led but this view was not completely shared by the operating companies. Newman and Rosenberg (1985) have argued that systems design is a heavily political process and MIS designers interests are quite different from those of users and while there is a "universal advocation of user involvement" (p395) in design and implementation, in practice the benefits of user participation are marginal.

Relations with suppliers

Relationships with suppliers is an area of immense importance for adoption and implementation of systems and yet its importance has often been lost in the literature that concentrates on user characteristics (Robertson and Gatignon, 1987). Ettlie (1986) has gone so far as to suggest that this is by far the most important aspect of a successful implementation. In particular he highlights the importance of the suppliers maintaining close relations, staying on site and participating in team building with customers after adoption to ensure that difficulties associated with reinvention and routinisation (Rogers, 1983) are solved. It is an area that communication theory, with its emphasis on barriers to information flow, is not well suited to explore. Some of the main problems facing any organisation in the adoption, implementation process are firstly, how is it possible to make sense of the information being received from suppliers when claims are often exaggerated, and secondly, how is it possible to control the activities of suppliers before, during, and after the adoption /implementation process?

The experiences of the cases studies throw some light on this area. We can identify three different strategies. ElectroCo followed a strategy of building close communication, clearly identified requirements, responsibilities, objectives and outcomes. The aim was to remove any ambiguity from the process and so prevent any unanticipated developments.

The approach at BritCo was more limited and the need to keep costs down played a key role in the eventual relationship with suppliers. The decision to go for BOS operating system was partly due to it's 'simplicity' but also, and perhaps most importantly, determined by price. The system came cheap and the outcome was that after the supplier went into receivership BritCo were left to their own devices which really meant rummaging through the manuals when things went wrong. At the same time there were difficulties in relation to software development and software bugs as the software house were no longer committed to the BOS system and so were very reluctant to provide the kind of support the organisation needed. This also means that future development is unlikely to be possible on the existing system. Further the staff at the software house were seen as computing academics who were alien to manufacturing and, as a result, not well equipped to understand the requirements of the organisation. The end result of this is that even minor modifications or additions to the software was very slow and expensive.

PlastiCo were in the difficult position of not being able to establish clear responsibility for problems. As noted there was an attempt to build in an element of control but this failed to achieve its objectives. The consultants were meant to be responsible for the effectiveness of software operation but PlastiCo still found itself dealing with the two different software houses directly. Even so there were problems in that the programmers who had written the bespoke elements had moved on leaving gaps so that no one really understood the system. This problem was compounded by the fact, as with BritCo, that the software houses are reluctant to devote a great deal of time to rectifying problems which is far less profitable than new accounts. In effect, despite attempts to build in safeguards PlastiCo found itself piggy in the middle.

Uncertainty, Security and simplifying the selection, and implementation process

It has already been noted that given the complex nature of CAPM systems that uncertainty is a problem at every stage for selection of hardware and software to developing a coherent implementation strategy. A major concern of managers is to find a way of simplifying the process to make it more intelligible, communicable and manageable.

The case studies demonstrate a number of different approaches to this. BritCo attempted to simplify the process of selection by opting for a basic off-the-shelf system that could be expanded as confidence and expertise developed within the organisation and to some extent they were successful in this. Most of the problems they experienced were 'people problems' as opposed to 'system problems' - getting people to trust and to use the system. On the other hand this has been at the expense of long term development as the system has not proved robust enough to cope with new or expanded needs.

PlastiCo chose a different route: that of dealing with uncertainty by making it some one else's problem - in this case the consultants. The consultants were seen as a buffer between the organisation and the 'obscurity of computer people'. The problem, in this instance, is that this decision rested upon an act of faith that the consultants knew what they were about, and the price of this was a loss of control over the process which they have now come to realise has resulted in an unsalvagable situation.

ElectroCo adopted an approach that both off-loaded the problem and yet enabled them to maintain control and the key to this was in the way they managed relations with the suppliers. The suppliers were required to offer not just a range of hardware and software systems from which their client could chose, they were required to develop just one solution to the problem that ElectroCo set them when they produced their list of requirements. Further they were also required to produce implementation methodologies so that the working parties could assess the degree to which they had understood their business, technical and organisational needs. In this way as much uncertainty as possible was removed from the process and clear responsibilities for achieving outcomes established.

Training and Education

Dealing with suppliers and developing a coherent implementation strategy is just one part of the whole process and there is a growing literature that has identified the importance of education and training as an integral component of the implementation process. Education is clearly at the heart of successful implementation strategies (Callerman and Jeff, 1986; White 1986). For them the major purpose of education is to 'unfreeze', the current culture of the organisation so that it will be ready for a new technical system. This change in culture is crucial and education needs to operate at every level from the management to the user to those responsible for implementation. Education, in this sense is more than technical training, it involves a continuous interaction between actors as the organisation goes through this shift. Users should be educated not only in how to use the system but equally to ensure that they do use the system both during and after implementation.

PlastiCo and BritCo underestimated the amount of time, energy and resources that needed to be the devoted to this. In both cases training appears to have been an ad hoc and peripheral activity. At PlastiCo, although formal training sessions were scheduled they were seen by staff to be too few, too far between and poorly resourced. As a result, a number of staff complained that they were really left to work things out for themselves and this had the effects of firstly, consolidating growing resentment of the system as it created more work for them, and secondly it encouraged them to find ways of working that reinforced existing templates and forcing the system, the bits of it they could, to work their way. Further the departure of the finance director had serious implications for system use as knowledge became fragmented around the organisation. He was the only person who had an overview of the complete system, everyone else had developed a working knowledge of their own bit but had no understanding of other modules or the links between them.

At BritCo the problem of training was compounded by the General Managers deep distrust of the shop floor work force and the possibilities that a computerised system would offer for sabotage. As a result actual inputting of data was restricted to one operative in a 'data processing' function and 'educating' operatives to produce accurate data sheets on time was left to her persistence.

At ElectroCo education and training was seen from the beginning as an essential component of success and a great deal of energy and resources were put into getting this right. Not only were formal sessions arranged on a regular basis but also personnel were inducted into the system via use of simulation training on a 'skeleton system' linked to a 'dummy factory'. In this way people could afford to make mistakes, which would not have disastrous consequences, before the complete system was implemented. It also provided an opportunity for fine tuning of the system as a result of feed-back from users.

Education aimed at developing user involvement, commitment and a cultural shift, is also important because there is increasing evidence to suggest that the implementation of CAPM systems needs to be understood as an ongoing organisational commitment as current systems become redundant for a number of reasons and to be replaced (Krupp, 1986). A common reason is that experienced by BritCo that the existing computer hardware may need to be upgraded and the existing system is not compatible with the new operating system. This requires an organisational attitude that is not only not resistant to change and development, but is able to make the required shifts to accommodate it. Top management may deem conversion to be necessary, but the user, as in the case of BritCo, is often committed to the existing, familiar system and resistant to change.

Importance of a small successes

Building on small successes has been identified as a key element in successful implementation. It is essential that such successes are incorporated into the programme of education so that there is a continuous loop of feedback of success. Without this there is a tendency to revert back to the old informal system and this has been cited as a major reason for failure (Callerman and Jeffs, 1986). Of all the cases it is clear that the staff at PlastiCo have been the most disheartened and distrustful of the system and this has largely be explained by the fact that the system has failed them on so many occasions that they have lost all faith in it. There can be little doubt that the attempt was far too ambitious in the situation and this is something that the other organisations were at pains to avoid. At BritCo Watson was clear that larger success can only be built upon smaller ones as people need to the won over by seeing the value of computerised systems. Thus, for him, the implementation of the accounts system prior to the production control system was an important element in the overall process because it demonstrated that a system could be implemented effectively, relatively painlessly and improve the working environment, and this approach is evident in both ElectroCo and FoundryCo. In the case of ElectroCo the earlier experience of MRP was seen as extremely valuable and in the case of FoundryCo the methodology was built upon demonstrating the value of a module in one plant before diffusing it to others. However, at BritCo the long period of parallel running seems to have diluted the impact of earlier success and there was indeed a reversion to more familiar systems.

CAPM and the rationalisation of existing practices and organisation

The introduction of a computer system into an organisation raises important questions surrounding existing practices and the degree to which they might have to change. Rogers model describes such processes in terms of redefining and restructuring, and clarifying. This question often polarises into a decision on whether to bend the system to match the organisation or bend the organisation to match the system. The case studies show very different approaches taken to this issue and highlight a number of important questions.

At PlastiCo the situation appeared clear, the implementation was in two phases with the first aimed at producing an organisational and control structure and efficient procedures and practices all designed to meet clearly identified business objectives. Given this, it appeared logical that the computer system should be designed to fit with these changes. The actors referred to this as 'overlaying' the computer system. BritCo took a similar approach and made a key criteria for adoption and implementation that the system should mimic existing manual systems as closely as possible down to the design of various print out forms. However, the rationale was quite different for each of these organisations. For PlastiCo the idea was that computerisation would greatly increase the efficiency of their new manual system. BritCo, on the other hand, were concerned to make the implementation as simple with as little disruption as possible. Child, et. al. (1987) have argued that the perceived absence of a need to change existing organisational structures represents a powerful marketing appeal and for BritCo, staying with the existing manual system and adopting a ready made system that seemed to mimic it most closely was seen as the best way to deal with both of these problems. On the other hand Strassman (1985) concluded that the reorganisation of existing structures during the process of implementation is essential to a successful outcome. The relationship between CAPM and the organisation needs to be understood in relation to clear organisational objectives. From this point of view Raynor (1987a) has referred to CAPM systems as goal driven instruments of change. This is an important point because it suggests that the implementation of a CAPM system can never be a simple matter of either transforming the existing organisation to meet the needs of the computer system or to simply slot the system into existing organisational grooves. It is a process characterised by negotiation to arrive at a new situation in which both organisation and computer system have evolved together (Clark and Staunton, 1989) to best meet the identified needs of the business.

Safizadeh and Raafat (1986) have noted the problems for implementation associated with the persistence of informal systems during and after the implementation of systems particularly that resistance is likely to stem from the fact that individuals have invested a great deal of time in developing their own way of doing things which is suddenly threatened by the arrival of a new formal system. Similarly, Saetnan (1991) studied the attempt to implement a surgical scheduling system, PREOP, in Norwegian Hospitals. She found that nurses were able to subvert the system to conform to existing practices:

> "Having learned to master PREOP by overriding parameters, nurses could force PREOP to set schedules exactly as they had before....PREOP became a slave to the old routines and thus reinforced them"
>
> (Saetnan, 1991: 434)

This is particularly acute in the case of CAPM systems because they mark a significant organisational shift towards much greater functional integration (Melnyk and Gonzalez, 1985) which can be perceived as a serious threat to an insular production department. They argue that such issues need to be addressed prior to implementation to avoid failure. BritCo had made a conscious decision to begin with a period of parallel running and this turned out to be problematic because it simply reinforced the already entrenched routines that operated prior to system implementation. It is interesting to note that E.L., at ElectroCo, predicted that this would be the probable outcome of this approach and was likely to end in implementation failure. This is because at difficult moments operatives will opt for the security of the old system, just as they did at BritCo (the period of parallel running eventual lasted for fourteen months!) For E.L. it was vital that training and education, coupled with undiluted commitment from the top, would instil the necessary faith in the system and an attitude to make it work

> "...when we went on the 12th January we had nothing else and nothing else to go back to. We told them we've got to make the system work....they either did believe in it or they didn't"
>
> (E.L.)

Interestingly, at PlastiCo, there was an attempt to avoid parallel running, at least in the way it occurred at BritCo. The manual system had been put in place with a view to computerisation and the transition was expected to be fairly straight forward. However the problems they experienced with implementation forced them into a situation of parallel running by default as operatives were forced to revert to manual systems that were springing up in parallel in an unplanned and unstructured way. The point is not to replace informal systems with a formal computerised system, as informal systems will always, inevitably develop (Safizadeh and Raafat, 1986). What is important is that any informal system in operation is appropriate to and complements the formal one. An enduring commitment to pre-existing informal systems is likely to undermine the new formal system.

Following the complete failure at PlastiCo the M.D. has reconsidered the way he would do it in future and the process he describes can be seen to be very close to the approach adopted by BritCo - Purchase a simple off-the-shelf package that would require very little modification of software, which could be seen running in a similar company. At the same time there are some differences in his new philosophy that might have helped solve some of the problems experienced by BritCo. Firstly, he now believes that it is necessary to bend existing working procedures to fit the system. Secondly, that standard hardware be purchased from a big supplier. And thirdly, he would commission one of the large consultancy firms to carry out the implementation.

Corporate vs local systems

It is interesting to note that in all the case studies there is clear evidence of tension between the centre and operating companies. At ElectroCo and FoundryCo it took the form of a struggle around the decentralisation of computer systems - a shift from the centre to the local. However at BritCo and PlastiCo, who had both moved to micro systems, it is clear that developments at corporate level would in future influence the course of events, and there is a push for standardised systems across companies. This highlights the issue that will be explored later around the nature and potentials of this technology and the implications for implementation. I.T. (Britco) is quite clear in his own mind of the purpose behind such developments - so that head office can increase mechanisms for surveillance and control.

The Characteristics of the Innovation

As we have seen Rogers develops a sophisticated notion of the characteristics of innovations that include the dimensions, relative advantage, compatibility, complexity, divisibility and communicability. These categories are a useful way of considering how innovations are perceived and decoded but, in the case of CAPM, they also pose questions. For example, Rogers argues that innovations that are compatible with an individual's/organisation's past experience and values are more likely to be adopted and pass successfully to the routinisation stage. However, as the case studies illustrate, and as we shall see later, in the case of CAPM, compatibility may lead the organisation to adopt a system that may be consonant with what they do, but not necessarily with what they *should* be doing. From this point of view CAPM needs to be understood in relational terms which concerns with the way in which outcomes are a product of negotiated change of both organisation and technology.

Complexity is a key dimension in the case of CAPM, but, and this is a key idea I will explore in depth later, it is inextricably linked to communication. Adopting and implementing CAPM is not simply a matter of paying attention to technical details, e.g. accurate data input (Monniot et. al., 1987; Corke, 1985; Raynor, 1988) but is also centrally concerned with a process of 'making sense' of CAPM and this process is mediated by information and discourses that emanate from a variety of sources but notably from suppliers.

One way that Rogers seeks to deal with complexity is via the notion of divisibility, the degree to which an innovation can be broken down into smaller parts and tried on a limited basis, and this is what BritCo, for example attempted to do. However, this process can also be problematic for a number of reasons. Firstly, it is difficult for both inexperienced, and experienced users alike, to decide just what sort of a system to build and to envisage how it will operate, and secondly because the ability to start small and grow is mediated by many other problems like hardware and software compatibility, the way in which expertise and knowledge moves in and out of organisations, the cost of new systems etc. The evidence from the case studies would suggest that starting small and growing is not so much about dividing up a technological artefact and adopting it piecemeal but is more centrally concerned with developing and maintaining the necessary organisational knowledge and culture that will enable the actors to control the process in the way that ElectroCo did.

Rogers Stages of Implementation

As we have seen Rogers characterises the implementation process in terms of a succession of stages from redefining and restructuring, which may include 'reinvention', through to clarifying, and finally routinising. Rogers is clear that these stages are sequential

> "Later stages in the innovation process cannot be undertaken until earlier stages have been settled."
>
> (1983: 362)

The commitment to this linear, cumulative process is problematic as it is clear from the case studies that events were not so cut and dried. These 'stages' certainly represent activities that actors were engaged in and they do help to capture the flexibility and fluidity of the process but they might be better understood as 'states' (Clark and Staunton, 1989) rather than stages as in reality these activities were often going on side by side and indeed were rarely settled, and an important part of the routinisation process involved continual restructuring and redefinition.

Rogers stages are an attempt to show how the implementation is an interactive affair that involves a process of joint accommodation as actors redefine their situation, and the nature of the innovation, to arrive at a working relationship. This is very valuable as it does provide an insight into the 'black box' and emphasises the active contributions of people, as opposed to the reactive notion that innovation is simply about passive acceptance or imitation. However, in the case of complex computer based systems there is a need for a shift in emphasis that gives the process of 'reinvention' a much more prominent place. Reinvention should not be understood simply in rationalistic terms of modifications both to the innovation and the organisation to ensure functional integrity. It is much more than this. Rogers himself refers to it as a 'struggle to give meaning to the new information as the innovation is applied to the their local context' (1983: 182). This idea is an important one that provides the possibility of moving beyond rationalistic frameworks in understanding and interpreting the innovation process. This issue is thrown into sharp relief when we turn to the issue of assessing success and failure in the adoption and implementation of CAPM.

Success and Failure

Rogers concept of reinvention is perhaps his single most important concept and yet he does not fully exploit its potential and it is, perhaps, when it comes to assessing the success or failure of the innovation process that Rogers model reveals its Achilles heal and gives a strong indication of the degree to which the pro-innovation bias is still evident in his work. The concepts he uses to analyse this are 'overadoption', 'innovation dissonance' and 'discontinuation, deimplementation'. As we have seen overadoption refers to the failure of an innovation because it was an irrational course to pursue in the first place *in the view of experts,* But what does Rogers mean by 'experts'? Does he mean the suppliers of technology like the one who sold BritCo a cheap but inflexible system, or the consultants who advised PlastiCo, the staff at central computing in FoundryCo, the suppliers to W.I. and Valley who have targeted the foundry sector, academics, the Institute of Production Engineers? Clearly the notion of 'expert' is entirely unhelpful and has its origins in communication and modernisation theory which are both wedded to the notion of technology transfer from an advanced centre to a backward periphery. But his model is far too simplistic in a setting where being able to 'make sense' of a technology and its relationship to organisational change is paramount.

Dissonance refers to the tendency for an individual/organisation to revert to prior practice and it is the role of the change agent to prevent this from happening so as to avoid deimplementation. Again this is too simplistic. Such a model might describe some of the events at BritCo but it does not shed much light on the events at PlastiCo. At PlastiCo deimplementation occurred not because of reversion but because the system simply did not work. There is still a commitment to innovation and computerisation and there is a strong case to be argued that the change agents and experts were responsible for the failure. The failure of the system is not necessarily a failure of innovative commitment or 'propensity' for innovation, as Rogers might put it, as PlastiCo fully intends to learn from the disaster and move the innovation process forward. The narrow focus on barriers to information flow and dissonance induced reversion is not appropriate to a process in which knowledge and expertise is highly problematised.

In the case of CAPM measuring success and failure is very difficult (White, 1986; Raynor, 1987a; Cale and Curley, 1987). With the exception of PlastiCo the organisations all felt their systems were successful. ElectroCo had gone the furthest in identifying criteria for success as part of the implementation system and, as is often the case, measured this in quantitative terms - cost savings, inventory reduction and control, stock turnover and measurable improvements in data accuracy. BritCo also claim quantitative successes including - generation of management information on a variety of areas and most importantly the fact that output has doubled whilst staffing has remained constant is also cited as the major achievement of the system.

Wight (1981) concentrates heavily on the measurement of success in technical terms, accuracy of data, inventory records, etc., but there must be other dimensions to an assessment of success and failure. There is evidence to suggest that the high failure rates associated with MRP system implementations, of up to 70% (Raynor, 1988), are a consequence of people problems and not technical problems (Callerman and Jeff, 1986; Burker, 1988). In particular, they insist that there is a need to change the way the organisation views itself, its processes, responsibilities, employees and relations with the external environment.

A successful implementation, then, is not just a matter of achieving certain bottom line figures, although these may be key indicators. It is actually very difficult to know that the system is responsible for these benefits as opposed to the organisational changes that accompany implementation - PlastiCo has also improved its efficiency despite the fiasco of the computer system implementation. The most important issue in successful implementation for Callerman and Jeff is success with which organisational reorientation is accomplished. True success, therefore cannot be measured only in technical terms - people must use the system. From this point of view should we see BritCo as a failure or a success: the system is not trusted and manual systems continue to be operated along side. If we apply the concept of dissonance then BritCo is clearly a failure, but if, on the other hand, we apply the concept of reinvention, then it could be argued that BritCo has successfully negotiated the minefield of hype, suppliers claims and reinvented the system to suit their own situation.

Apart from these bottom line assessments there are other less tangible measures of success. For example, at BritCo I.T. talks of an increased 'professionalism', and ElectroCo of having dispensed with the manual system altogether. Perhaps success and failure need also considered in terms of value added so that they take into account the degree to which organisational learning has moved on.

A further problem in assessing the level of success and failure of CAPM implementation is that of identifying just what it is that is being measured. In all of the cases the implementation of the computer system was accompanied by considerable organisational change and it is difficult to unravel just what the source of measurable improvement is, the computer system or the organisational changes. At PlastiCo the implementation of the computer system was an abject failure and yet the company was still turned around and managed to reduce inventory, improve delivery times etc, and brought to profitability so it is clear that the organisational changes must have been responsible for this.

The problem is that assessments of success or failure that operate at the level of technical specification - that the correct hardware and software have been adopted, and operational functionality - that the computer does what it is supposed to do and is used, tend to fall into the trap of pro-innovation bias and privilege the 'technology' over the context in which it exists. BritCo and PlastiCo are only failures if we take as our starting point the definitions of success propounded by professional production engineers. It could be argued that the complete failure of the system at PlastiCo and the partial failure at BritCo do, in fact represent a success insofar as they represent the companies successfully either 'reinventing' the innovation or discontinuing it as the best solution to *their* problems. Further if we shift the ground from an examination of 'the computer system' to what Kling (1991) calls 'computer based systems', which refers to a context in which the computers cannot be separated from human and organisational elements then 'reinvention' does not just refer to the 'the computer system' but to the whole context. Viewed in this way discontinuance of the 'computer system' could be construed not as failure but as a successful reinvention of the 'computer based system'.

The pro-innovation bias holds that innovation is always good and that failure to innovate is due to low levels of innovativeness, and failure to implement is due to a whole host of individual or organisational shortcomings. To remove the pro-innovation bias it is necessary to ask *why* should we adopt this technology? *Who* says its is the most appropriate solution to our problems? *Who* defines what is success and what is failure? In short, the removing of the pro-innovation bias requires a problematisation of the innovation itself.

A major weakness in the Rogers model is the treatment of the environment as a spatial context through which innovations spread, and although this might be balanced the potential richness of the concept of reinvention he does not really exploit this. Along with professional production engineers, he tends to reify the innovation as a neutral objective entity so that any problems are located with adopters not the innovation itself.

Problematising the innovation requires an understanding of the way in which the environment operates in creating and promoting the innovation. The question then shifts from one which asks why are so many not adopting this innovation to why should they? It moves from what is wrong with organisations that fail to implement successfully, to what is wrong with the innovation that makes it impossible for them to do so. In this sense the success at ElectroCo can be understood not just in terms of their organisational expertise in managing the innovation process but also by the fact the innovation happens to be appropriate to their needs. By the same token PlastiCo's failure should be understood not in terms of lack of expertise - they had plenty of that - but by the unsuitability of the innovation to their needs.

These questions translate to a bigger problem for CAPM as a succession of surveys show that 'failure' is the typical experience of companies adopting and implementing MRP based computer systems (Whiteside and Ambrose, 1984; Galvin, 1986; Lincoln, 1986; Raynor, 1987a; Brady, 1988; Sheridan, 1989; Schulke, 1992). The pro-innovation bias that pervades both Rogers work, and accounts of CAPM from the production engineering literature, prevents them from producing an account of the technology that is sophisticated enough to enable us to make sense of the processes inside adopting organisations. In order to achieve this we need to take another look at this technology (CAPM) in particular, at conceptualisations of technology in general. The next chapter, therefore, will review a broad literature on technology which will provide a richer theoretical framework to enable us to return to the innovation with a more sophisticated appreciation.

CHAPTER 7

The Study of Technology: From Objectivism to Social Construction

Habermas (1972) has suggested that theory is invariably and inevitably located in human interests and that knowledge is always a reflection of those interests. Accounts (of technology) that appear on the surface to be objective and dispassionate treatise turn out, on closer investigation, to be imbued with and shaped by sets of assumptions and preconceptions, and to be bounded by the interests of those socially located theorists who have 'turned their gaze' (Foucault, 1973, 1980) to one area of study or another. This is nowhere more true than in the writing on technology which is a central preoccupation of the modern era (Luke, 1990).

That is not to say that interest in technology has only appeared in recent times but that the idea of technology, its nature, its inner potentialities and its relationship to human development, is peculiarly linked to the very particular history of location and period. What we take technology to be is inherently linked with what we have taken ourselves to be. The language of technology has for a long period been anchored in a discourse of modernity from which it has taken much of its force. This discourse is ineluctably bound up with notions of rationality, control, progress, and technological development. Some social theorists, like Durkheim, have been unbounded in their confidence of the transformative nature of technology that would cement together a fragmented world in an extensive division of labour. Others, like Marx, have tempered their optimism with a critical eye, whilst others like Weber described the relentless unfolding of administrative technologies and the enslavement of the modern world to rational, instrumental logic. These very different visions share the common thread that technology holds a special place in the modern world.

Further, this discourse of modernity informs every aspect of our technology interests, from grand theoretical schemes to the day to day decisions made by managers. If classical theorists were concerned to demonstrate that technology was to be the vehicle for human progress, then modern managers at every level have often been guilty of assuming that all problems could be solved through a quick 'technical fix'. This predilection has been reinforced by pushers of computer technology who are only too keen to supply that fix.

It may be true that this discourse is now being eroded, at least in academic circles, by a growing realisation that this history is just one possibility amongst many. As Lyotard (1984) has argued we have lost faith in the meta-narratives which give meaning to our universe and to rediscover meaning we must look with fresh eyes upon the landscape we have built.

A great deal of writing on technology, then, can be located in a broader discursive framework of modernity, but also Jamison (1989) provides a periodisation of development of theories of technology and technical change in order to show how they represent responses to contemporary socio-economic preoccupations. So theories of technology are both responses to socio-economic conditions, but are also located in an intellectual web of assumptions and preoccupations that are derived from the experiences and intellectual tradition of western industrial powers in the modern period. This discourse of modernity stresses the rational nature of life and elevates science to the pinnacle of epistemological schemes. The promise of modernity is a better world, in which nature has been tamed. This will be attained through the application of science, rational organisation and technological improvement. The threads of these assumptions are inescapably woven into the back cloth of both academic and lay understandings of technology and have only recently been challenged by more critical perspectives.

Theorists of technology have approached the problem from a number of different directions. Jamison (1989) has argued that theoretical interests and foci tend to follow practice and therefore reflect broader concerns over socio-economic conditions. Consequently for many theorists the main issue is the relationship between technical change, or innovation, and the course of economic development. Views of this kind tend to be associated with theories of cycles of economic change. Allied to this concern with the relationship between economy and technical change is another with the relationship between science and technology. Is technical innovation directly associated with scientific discovery or is the relationship more complex? We could add to Jamison's periodisation the preoccupation through the 1980's with economic decline (Gamble, 1985; Armstrong et. al., 1984) and possible technological solutions to the problems of increasing competitive efficiency. Such approaches have been criticised for allowing broad concerns of economic development to obscure the nature of technology itself which was consigned to the 'black box' which other theorists have tried to prize open. More recent approaches then have focused upon the nature and process of technical change itself. These tend to be more sociological in character and draw heavily on the work of Thomas Kuhn.

The way in which we understand technology then has gone through a number of transformations and many domain assumptions have been challenged.

It was noted earlier that Rogers' model provides a useful but ultimately limited basis for understanding the nature of CAPM and issues surrounding adoption, implementation and use. This, to a large extent, stems from his tendency to objectify innovations as things, even if very complex things, to be diffused through populations. This, in my view, can be seen as an instance of the instrumental logic of the modern period that translates into a concern for the way in which objects become subject in one way or another to rational processes which can be identified, codified and applied in other contexts. However to understand complex 'computer based' technologies (Kling 1991) it is necessary to move beyond objectivist accounts to grasp the way in which the technical and social become inextricable linked in processes in which technology is not simply diffused, but even constituted.

In this chapter I will attempt to map out the terrain of technology theory, to draw out the underlying assumptions, and show how they are tied to the discourse of modernity. I will also outline the growing challenge to this discourse and emerging conceptions of the nature of technology. I will attempt to identify how the themes outlined above have been translated into a number of different accounts of technology and technical change and I will argue more recent ideas represent an important departure that adds greatly to our understanding. In so doing I will try to chart the way in which neoclassical rational, objectivist accounts of technology have been undermined by a growing interest in the ways in which technology can be seen to be socially constructed.

The starting point for the discussion is the debate with neoclassical rational, economic models which take the form of the push/pull debate. Problems around conceptions of rational choice lead to alternative formulations designed to place limits on human rationality and place actors in bounded situations of one kind or another. From here a number of perspectives are discussed and in the process the social content of technology is greatly expanded.

Invention and Innovation - Demand Pull and Technological Push

Neoclassical theorising on innovation, technology and change weld the commitment to progress to a confidence in the inherently rational nature of that process. It is worth examining the debate on the rational nature of innovation as, in my view, one of the key brakes on the further development of Rogers' perspective is that he is, at least implicitly, firmly anchored in this perspective. But the assumptions of neoclassical economics do not translate well to an understanding of organisational process, and Rogers has been unable to move beyond its limitations.

A great deal of the literature on the economics of technological change has been concerned with two major issues: first, questions of origins (invention), and second with levels of inventive and innovative activity. In one way or another theories of this kind are concerned with explaining the rate and the direction of change in technical knowledge. Elster (1983) explains that there are two main approaches to explaining technical change. The first is that technical change is a rational goal-directed activity and the second is to see technical change as a process of trial and error, as the cumulative addition of small and largely random modifications of the production process. These two processes can be characterised as, on the one hand, a rational process which emphasises future goals and, on the other hand, an evolutionary process which emphasises past history. These two approaches are best encapsulated in the neo-classical 'demand-pull view' (e.g. Schmookler, 1966) which sees market forces as the main determinant of technical change, and the Schumpeterian and Neo-Schumpeterian 'technology push' (Mowery and Rosenberg, 1979; Dosi, 1982; Freeman, 1982) which attributes to technology a more autonomous role. The major distinction between the two approaches then is the role attributed to market signals.

Criticisms of such perspectives tend to operate at different levels. Some of these are related to neoclassical theory at a general level (Harcourt, 1972) but others (e.g. Dosi, 1984; Freeman, 1987) take issue with the logical and practical difficulties in interpreting the innovative process through this approach.

First, the focus of the above approach is very much on the *incremental* changes to existing products and presents a very passive idea of mechanical reactiveness to technological change. One of the major criticisms of the demand-pull hypothesis and of the 'related rational' choice versions of technical change is the problem of *radical innovation*: major innovations which cannot be seen as the product of modifications to an existing technique or process. This, of course, is the basis of Schumpeter's identification of the role of the *entrepreneur*., which partially underpins Rogers' notion of the 'change agent'. Freeman (1987) points to the case study of emergence of the electronic computer (Katz and Phillips, 1981) which demonstrates that before 1950 there was no commercial demand for computers. He argues that this case study seriously undermines any simple notion of demand-pull and suggests that more complex forces like the role of the military and of the push from scientists and technologists who want to promote technical advance.

Second, such an approach rests upon an abstract view of technology as a versatile and flexible mechanism that can be directed with little difficulty or cost. This ignores changes over time in the inventive capability that do not bear any direct relationship with market conditions. Market demand may be an important factor in explaining the success of innovation. But it does not help to explain the timing of particular innovations. It would be surprising to find that companies were busy producing items for which they perceive there to be no market, and in this sense market signals constitutes a necessary but not sufficient condition for innovation (Dosi, 1983).

Neoclassical economics entails assumptions about rational behaviour and this implies perfect information of possibilities upon which rational decisions can be made. The very nature of innovation creates immediate problems for such a view because it is essentially a phenomenon which creates uncertainty and more information. Thus innovation is an information-generating activity (Coombs et. al., 1987) which contradicts the notion that information is available at the outset. Not only is information scarce but also access to knowledge is likely to be one of the most influential determinants of success.

From the Rational to the Routines: Search and Selection, Routines, Regimes, Paradigms and Technological Trajectories

Neo-Schumpeterian economists reject this mainstream neoclassical approach to technological change. Like Schumpeter they are keen to put human beings into the equation. They are particularly critical of the assumption of perfect rationality and the corresponding 'maximisation metaphor'. In contrast Nelson and Winter take an evolutionary perspective which sees firms as clusters of 'routines' - ways of doing things and ways of determining what to do. Routines makes 'choosing' a fairly automatic affair. Organisations are made up of routines and these are subjected to selection pressures from the market (selection environment) which determines which routines are successful within a population of firms and which are not.

Nelson and Winter have attempted to ground Schumpeter's theory in analytical and empirical detail. Of particular interest is their rejection of neoclassical notion of *maximising rationality* and *equilibrium,* and the substitution of *search* and *selection* as alternatives. Winter (1964, 1971, 1975) has argued that such neoclassical notions need to be replaced by the concept of *satisficing* an arbitrary restriction of the set of possibilities to be scanned that cannot be justified by rational argument. Satisficing is not an option to choose, it is intrinsic to the nature of all purposive behaviour which serves to put limits on rationality.

The notion of satisficing represents an attempt to reconcile the contradiction in neoclassical economics between rationality and optimality. That is by specifying that rationality must sometimes be understood as finding an alternative 'good enough' for one's purpose rather than the 'best' (Simon, 1954, 1978). It follows then that firms cannot be expected to have, ready to hand, a detailed knowledge of techniques other than those which they are currently using. Nelson and Winter liken surveying available knowledge to surveying a landscape on a hazy day. Some things are close enough to be seen clearly, others remote enough to be totally invisible (Nelson, 1980). The implication of this is that if a firm is driven to innovate, to change a technique, there is no guarantee that the search for a better one is going to be successful. As the relevant information is not available at the outset, the acquisition of information and the amount of time invested in this activity is an important determinant of the outcome.

Thus the notion of *search* is a fundamental element in Nelson and Winter's model. This is closely linked to the second notion of *selection* of firms by the market. Firms which have better rules for searching than others, or who simply happen to find new techniques will be favoured.

In this view innovation is analogous to genetic mutation and this is also subject to patterned routines or search heuristics. Sometimes these patterns are particularly marked and these are taken as evidence of the existence of a 'technological paradigm' or 'regime'. The prime example is the Douglas DC-3 model of the 1930's which guided aircraft design for more than twenty years by defining a technological regime - metal skin, low wing, piston engines. Nelson and Winter are clear that this is a cognitive concept which relates to the technicians beliefs about what is feasible or worth attempting (1982: 258-259). Thus innovation involved exploring and articulating the boundaries of the paradigm and, in turn, leads to the rise of 'technological trajectories'.

This theme is further developed by Dosi (1982, 1983, 1984). He argues that a theory of technical change must be able to define and articulate the complex nature of the interactive mechanism that links the environment with direction of technological change. To this end he attempts to provide a theory that takes into account the factors that, he argues, have been demonstrated by empirical research to characterise the innovative process (1984: 12).

Technical change does not occur at random in response to ever shifting market signals for two reasons. First, the directions of change are often defined by the state-of-the-art technologies already in use and second, technological advance is the function of the technological levels already achieved by them. Consequently the evolution of technologies through time presents some significant regularities and one is often able to define 'paths' of change in terms of some technological and economic characteristics of products and processes. He draws on the work of Kuhn to articulate the idea of a ‘technological paradigm’; Dosi's twin concept is that of a 'technological trajectory'. This represents the normal pattern of problem solving activity, and both defines and sets limits to the understanding of progress, on the basis of the technological paradigm. Following Nelson and Winter (1977a) and Rosenberg (1976) Dosi argues that once a path has been established it develops a momentum of its own called a 'natural trajectory'.

The kind of account outlined above manages to avoid the problems of neoclassical theories of technical change that are dependent upon rational behaviour, perfect information and market signals. There is much to recommend the 'technical push' view. The boundedness of rationality is well encapsulated in the idea of a 'technological paradigms' which puts limits on possibilities, and 'technological trajectory' which puts limits on the significance of market signals, and suggests a more active innovative role for technologists.

However this perspective is not without its problems. One criticism is that Dosi's view on the relation between science and technology, which he sees as sequential or linear, is flawed and the 'two cultures model' of Barnes and Edge (1982: 147-154) is preferable. In this model the relationship between science and technology is not a simple hierarchical one of science "having implications for" technology which "applies" the findings of science. By contrast the relationship is a symmetrical one, with both forms of activity possessing their own distinct cultural resources, although both may also, occasionally or more regularly, draw on the cultural resources of the other.

Perhaps the most serious criticism made by Van den Belt and Rip (1989) concerns the nature of selection environments. They argue that the analogy with biology is limited. Elster (1983) has shown that in biological evolution, although mutations are random, selection is deterministic; that there are well defined criteria for accepting or rejecting any given mutation. This is not the case in technological development. Here intentions and expectations play a role and actors can make choices and anticipate the reactions of others. Further human actors try to influence the reactions of others and change their environments and so the assumption of a selection environment which is truly independent of a particular technological trajectory is dubious. This, of course, is the very issue picked up by Pinch and Bijker and calls for a much broader treatment of 'the social' beyond (bounded) rationality and search routines. In the following section we will see how Hughes (1983, 1989) begins to break down the barriers between environment and the innovative activity.

Kuhn's model itself calls the idea of an independent selection environment into question. For him the success of a paradigm, at the start, is merely the promise of success and so it must be protected from the myopia of natural selection and so a niche is created which protects it.

Technological Systems

Despite these shortcomings the above model has managed to break with the naive rationalism of neoclassical economics and to incorporate an important sociological dimension into an account of technological change. This task is also central to the work of other theorists. A great deal of interest in recent years has focused, in one way or another, on charting the various ways in which the social impinges upon the technical.

Hughes, for example views technology in terms of a "systems" metaphor that stresses the importance of paying attention to the different but interlocking elements of physical artifacts, institutions, and their environment and thereby offers an integration of technical, social, economic, and political aspects. He employs the key concepts "reverse salient", and "critical problem".

In his account of the growth of electricity supply systems (1983, 1989), he makes no distinction between the technological and the social. Technological systems are social constructions because they are built by "system builders" who have to *simultaneously* engineer matters (such as the design of the filament lamp), economic matters (such as the need to compete on prices terms with existing gas suppliers), and political matters (such as legislative frameworks within which the electricity supply system developed): successful engineering is 'heterogeneous engineering' (Law, 1989). Hughes, attempts to bridge the gap between the micro and the macro with his concepts of the reverse salient and critical problem, and as distinct from paradigm models he argues that system builders make no distinction between the system and the environment - system development and environmental remoulding go on hand in hand.

His model has three components. First it contains a stage model for the development of technology. For example, the development of electricity moves from electric lighting systems to universal lighting and power systems and finally to large scale regional power systems.

Second, each stage is eventually characterised by the appearance of a reverse salient in the advancing technological front.

> "A salient is a protrusion in a geometric figure, a line of battle, or an expanding weather front. As technological systems expand, reverse salients develop. Reverse salients are components in the system which have fallen behind or are out of phase with the others. "
>
> (1989: 73)

These reverse salients , in turn may be broken down into critical problems which attract the attention of relevant practitioners. At each stage these critical problems trigger the emergence of characteristic types of problem solvers of which Hughes identifies three kinds, the 'inventor entrepreneur' (e.g. Edison), the 'manager entrepreneur' (e.g. Insull), and engineer entrepreneurs (e.g. von Miller)

Finally, each phase produces a particular "culture of technology" characterised by a set of distinctive values, ideas and institutions. Some values may be quite general like , for instance, technical efficiency but take specific forms within a system. These cultures of technology also comprise specific organised knowledge that, by the beginning of the twentieth century, constitute a virtual science of technology (Constant, 1989). The technology itself, its systematised knowledge, and its culture is embodied in a variety of economic organisations and social institutions. It is this culture of technology, expressed both in large scale organisations and institutions and in the career commitments of individual practitioners, that creates technological momentum, the tendency of technologies to develop along defined trajectories unless and until deflected by some external force or internal inconsistency.

Hughes has attempted to locate technology and technical change in a broader socio-economic milieu than Nelson and Winter or Dosi. Some critics, however argue that Hughes does not go far enough. MacKenzie and Wajcman (1985) argue that systems should not be taken to imply stable conflict free entities. They are constructs and hold together only as long as specific conditions prevail. Neither are reverse salients given, independent of the actors concerned. In order to identify a reverse salient it is first necessary to agree on what constitutes a barrier to progress and this in turn rests upon a prior agreement about what one is trying to achieve. These cannot be taken for granted; reverse salients are more readily identified in retrospect.

The causal relation between reverse salient and critical problem is not one way as critical problems may be defined selectively in relation to already existing solutions. For example, MacKenzie (1989) uses the example of accountants and engineers who develop widely different interpretations concerning the nature - technological or financial of suspected reverse salients.

Hughes shows that any account of technical innovation or change must take into account social as well as technical environments but his scope is still narrow as these environments tend to represent resources for system builders. Other approaches go further by showing how very broad social influences impact upon trajectories of socio/technical change and even the nature of technical artifacts themselves.

Actor Networks

The "Actor Networks" approach is associated with the work of Michael Callon, Bruno Latour, and John Law. This perspective extends the systems approach and aims to break down the distinction between human actors and natural phenomena. Both are treated as elements in "actor networks". This approach also reverses the usual relationship between participant and analyst and cast the engineers as sociologists. In other words, in trying to extend successfully the actor network, the engineers attempt to mould society.

Law (1989) attempts to integrate the ideas of Hughes with those of Callon, and the historical and network approach. Like Callon he argues that the social is but one element of a larger system. At times the social may be dominant but this is completely contingent and a matter for empirical study. Like Callon he makes no distinction between animate and inanimate elements nor sees a need to treat the different elements in different ways.

Law uses the establishing of the Portuguese spice trade and the subsequent domination of the Indian Ocean in the fifteenth century as a case study to illustrate the process of system building or heterogeneous-engineering. He outlines how the seagoing and load bearing limitations of the galley and the problems of ocean sailing were overcome by three related types of technological innovation. Firstly, the development of a mixed-rigged seagoing vessel. Secondly, the availability of the magnetic compass, and thirdly, the invention of the *volta*, a navigational circle which enabled sailors to move away from the coast to use prevailing winds and drifts as seagoing aids. Finally, new metricated navigational techniques and improvements in gun technology enabled the Portuguese to dominate the Indian Ocean. Law warns us not to fall into the trap of technological determinism and highlights the contingent nature of the relationships between natural forces, maritime practices etc.. He says that his main aim is not to provide a realist explanation by prioritising the role of nature but to demote the role of the social from the privileged position it occupies in social constructivism.

Callon (1980, 1989) also attempts to demonstrate that the neat distinctions often made between the technical (invention?), economic, political, social (innovation?) are artificial and that they are inextricably bound up in a single organic whole. He illustrates this thesis through a case study of the electric (VEL) car in France in the early 1970's.

The VEL project was developed by a group of engineers working for EDF (Electricite de France). Their programme went beyond the techno-scientific problems that would have to be solved and included an analysis of French social structures that would need to be altered for their project to succeed. The plan which they presented for VEL determined not only the precise characteristics of the vehicle they wished to promote but also the social universe in which it would function. Thus as well as concerning themselves with technical issues surrounding the development of such a vehicle, e.g. accumulators, fuel cells, electrodes, electrons, catalysts, and electrolytes, they were also involved in the identification of consumers, new social movements and ministries which would create the new world in which the electric vehicle, rather than the automobile, would have a place.

> "The ingredients of the VEL are the electrons that jump effortlessly between electrodes; the consumers who reject the symbol of the motorcar and who are ready to invest in public transport; the Ministry of Quality of Life, which imposes regulations about the level of acceptable noise pollution; Renault, which accepts it will be turned into a manufacturer of car bodies; lead accumulators, whose performance has been improved; and post-industrial society, which is on its way. None of these ingredients can be placed in a hierarchy or distinguished according to its nature. The activist in favour of public transport is just as important as a lead accumulator, which can be recharged several hundred times."
>
> (1989: 86)

Callon identifies a tension between the engineers at EDF and the engineers at Renault which did not revolve around technological issues but around social visions of modern France and its evolutionary tendencies. These visions Callon equates with the sociological debate of the early 1970's between Alan Touraine and Pierre Bourdieu.

Touraine's position is derivative of Marxism, but it is not the class struggle which is the central tension of modern life. Rather it is that between the large *producers* who seek to define and manipulate needs and aspirations (Galbraith ,1971; Marcuse, 1964) of *consumers*. This conflict has generated the rise of new social movements that challenge the power of the technocracy and the paradigm within which it is situated. This new type of conflict is at the heart of what Touraine refers to as the Post-Industrial Society.

Whereas Touraine remains faithful to the Marxian notion of polarised positions (albeit producer and consumer as opposed to worker) Bourdieu's vision, in Callon's view, is characterised by diversity and differentiation and struggles for power more characteristic of the sociology of stratification. Both have placed the consumer at the centre of their analysis but for Touraine this represents the basis of a new class struggle, whereas for Bourdieu consumption is tied to logics of social distinction.

These differing interpretations of the logic of modern society have very different implications for the future of the automobile. For Touraine we are on the threshold of a brave new world of ecological purity and where the false needs imposed by producers will be replaced by true needs championed by the new social movements. In this world the noisy polluting motor car has no place. This is a world awaiting the electric vehicle. For Bourdieu, on the other hand, this is utopian wishful thinking. A society, based on difference and social differentiation will not give way to the uniformity of ecological soundness. The motor car is a symbol of status which reinforces the differentiation upon which our society is built. Thus the car is not destined for the scrap heap of history. On the contrary its future is linked with the search for difference in a differentiated society. Evolutionary changes to a symbol which so expresses the essence of our society can inevitably be incremental and careful. Greater differentiation, not less, is the message.

It was Touraine's vision which inspired the engineers at EDF. Callon is clear that they were not concerned only with technological development but with the social evolutionary momentum of modern France. The engineers at Renault were more in tune with Bourdieu. Current public opinion concerning the motor car was a short term dissatisfaction which was a signal for further development not abandonment. In the event technical problems plagued the VEL project, the protest movements were dissipated and the traditional motor car was rehabilitated, albeit with modifications.

> "This was a remarkable controversy. The engineer-sociologists of EDF were matched by Renault's engineer-sociologists, who developed a sociology that in its arguments and its analyses was close to Bourdieu's. EDF against Renault is, on another stage with different stakes and new rules, Touraine and Bourdieu."
>
> (1989: 92)

However, unlike the theories of Touraine and Bourdieu, the theories of engineer-sociologists are open to and subject to falsification.

Callon is clearly concerned with tearing down the walls which artificially separate what for him is a highly integrated web of interaction and the artificial boundaries between technical (invention?), economic, political, social (innovation?) dimensions. For him an 'actor network' is *heterogeneous associations and the mechanisms of their transformation or consolidation* and this might refer to electrons, batteries, social movements, industrial firms, and ministries.

But another important aspect of Callon's analysis is the central role he ascribes to discourse in the construction of technical artifacts. To understand the VEL project it is necessary to understand the social meanings that make it possible.

The Social Shaping of Technology

We have seen above that rationalistic approaches to technology, to a greater or lesser degree, link it directly to the innovation process and economic development. Approaches that emphasise paradigms and trajectories show how the social impacts on technological change so as to make it more uncertain and tied to particular design interests but the social is still bounded by the paradigmatic horizons of designers and engineers: social interests are defined largely in terms of technical accomplishments and outcomes in terms of selection mechanisms. Hughes, shows that the relationship with the environment is more symbiotic. Other approaches go further still to show how technical change and technical artifacts are, in one way or another inscribed with broad socio-political characteristics.

The social shaping perspective takes this insight further by expanding the role of the social to include dynamics at a societal level. In attempting to understand technology and technical artifacts two major questions arise. Firstly, does technology have effects? And secondly, what shapes technology before it is able to have any effects? There are two main issues here: firstly the idea that technical change is somehow *autonomous*, that it exists outside of or independently of society; and secondly that technical change *causes* social change. So that for example, some authors see the micro chip as causing large scale social change (Large, 1980; White, 1978). This is the issue with which has been picked up in the work of Noble (1977, 1979, 1984) and by MacKenzie and Wajcman (1985).

In respect of the first question there are a number of points to be made. Firstly, that the characteristics of a society play a major part in deciding which technologies are adopted and this must dent confidence in the view that technology is independent. Secondly, the same technology can have different 'effects' in different situations. Technology can thus be seen as one element in a much larger dynamic - how does society work. Winner (1977, 1982) has shown that technologies are not altogether neutral but are often linked to and embody particular social interests. He shows for instance how bridges in New York were intentionally designed to be low level in order to inhibit the mobility of the poor, black population who depended upon high level buses for transport: bridges were thus 'inequality in built form'.

On the second question MacKenzie and Wajcman (1985) identify a number of common approaches. One is to say that society has only a marginal role as technology is shaped by science and science is itself unaffected by society. However they point to a number of studies that have demonstrated that science is deeply embedded in the social, political and economic context (Barnes and Shapin, 1979; Collins, 1981, 1982; Barnes and Edge, 1982; Knorr-Cetina and Mulkay, 1983; Shapin, 1982). Further science and technology have not always been closely connected activities - the water mill, the plough, the spinning wheel, the spinning jenny, even the steam engine - these crucial inventions were in no real sense the application of pre-existing science. (Cardwell, 1971, 1972). Where the two are seen to be closely related it is by no means always a one sided relationship of science influencing technology (Barnes and Edge, 1982) - the dependence of science on the computer is just one example.

Another way of arguing that technical change is autonomous is to say that technology is shaped by technology (Ellul, 1964; Winner, 1977). This view derives from the critique of the 'great inventor's' 'flash of inspiration' notion of technological change. Rather than inventions being the result of inspiration, it is argued that given certain conditions inventions are inevitable "Given the boat and the steam engine, is not the steamboat inevitable? (Ogburn and Thomas, 1922, in Mackenzie and Wajcman, 1985). The critique of inspirational invention has been deepened by Gilfillan (1935a, 1935b) who shows that the gradual evolution of the ship was the product of 'a perpetual *accretion* of little details the authors of which were normally anonymous skilled craft workers and not great individual heroic inventor figures. Similarly the work of Thomas Hughes shows how the achievements of the 'great inventors' like Edison and Sperry are the products of painstaking development and improvement of existing technology. The theme of incremental technical change is also highlighted by Rosenberg's (1982) notion of 'learning by using' - feed back from experience of use into both design and way of operating things. Thus new technology is not the product of disembodied flashes of inspiration but of existing technology. This applies even to apparently revolutionary developments as Constant's (1980) study of the change in aircraft propulsion from propeller to jet shows.

MacKenzie and Wajcman agree that technology is an important precondition of new technology which provides the basis of devices and techniques to be modified, and is a rich set of intellectual resources available for imaginative use in new settings, but they argue that it is not the only force shaping new technology. They attempt to demonstrate this by examining two of the most plausible attempts to argue that existing technology is more than just a precondition of new technology, but is an active shaping force in its developments. These attempts, as we have seen, focus around the ideas of technological 'paradigm' and technological 'system'

They argue that the incorporation of Kuhn's ideas into the field of technology has only been partial and tends to emphasise one of Kuhn's meanings, that a paradigm is an entire constellation of beliefs, values, techniques, at the expense of another, philosophically richer meaning that a paradigm is an exemplar - a particular scientific problem-solution that is accepted as successful and which becomes the basis for future work.

Because we find technologists operating within a paradigm it is tempting to expand this into a self explanatory notion like a technical trajectory (Dosi, 1982) but, they argue, this misses the most fundamental point of Kuhn's concept of paradigm: the paradigm is not a *rule* that can be followed mechanically, but a *resource* to be used. There will always be more than one way of using a resource and so the same paradigm may be developed differently. To illustrate this they cite the example of American and Soviet missile design. A paradigm does not develop simply according to its own 'internal logic' or 'technological trajectory'.

Trajectories only look natural after the event and they cite Hughes study of the development of chemical processes in a German firm which conditioned as much by factors outside of the firm, particularly the need of the German wartime state's need for independence from external sources of raw materials. Du Pont, in America developed the same paradigm along a very different trajectory.

What then does shape technology? For MacKenzie and Wajcman, drawing on a Marxian tradition, the answer is twofold - technology is shaped by economic and social relations. This is well illustrated by Noble (1984) in his study of machine tools which also takes issue with the 'autonomous technology' view of technical change

> "For the technological determinist, the story is pretty much told: Numerical control leads to industrial concentration and greater managerial control over the production process. The social analyst, having identified the cause, has only to describe the inevitable effects. For the critical observer, however, the problem has merely been defined.....Why did this technology take the form that it did...and why only this technology? Is there any other way to automate machine tools, a technology, for example, which would lend itself less to managerial control?"
>
> (Noble 1984: 110)

Noble explores this issue through an investigation of two different (competing) methods of automating machine tools. The first was record-playback, which involved a machinist making the parts while the motions of the machine under his command were recorded on magnetic tape. This could then be used to control the machine to make other identical parts. Record-playback was a multiplier of skill, simply a means of repeatability. The intelligence of production still came from the machinist. The second was numerical control and this was based on an entirely different philosophy. It is mathematically controlled from the design of the part onwards and was thus a means of circumventing the role of the machinist as a sources of the intelligence of production.

Noble's argument is that to understand why this technology took the form that it did it is necessary to analyse the social context in which it was developed. To do this he analyses the horizontal and vertical relations of production.

The choice of both hardware and software was greatly influenced by the US airforce who sponsored the development and thus released the large firms from the usual cost considerations of producing innovations for the market. This is of some importance because NC was a more expensive technology than play-back, which was cheaper and less complicated and more attractive to smaller firms. NC had a number of technical advantages in relation to the needs of the US Airforce but this, according to Noble is only part of the reason for its success.

> "..especially in the eyes of its MIT designers.....it [NC] was a symbol of the computer age, of mathematical elegance, of power, order and predictability, of continuous flow, of remote control, of the automatic factory. Record-play-back, on the other hand, however much it represented a significant advance on manual methods, retained a vestige of traditional human skills; as such, in the eyes of the future (and engineers always confuse the present and the future) it was obsolete."
>
> (Noble, 1984: 116)

Noble is arguing that economic explanations are not enough to explain the drive for total automation which NC represented. Rather it was also informed by an ideology of control, in this instance an engineering ideology which mirrors capital's distrust of labour and strives for ever increasing control of the production process. Automation of machine tools is located in the struggle for control over the production process and, in Noble's view what is today called automation is conceptually a logical extension of Taylor's scientific management.

The Social Construction of Technology (SCOT)

We can see that the above approaches have done much to undermine the rationalist, objectivism of classical accounts of technology by showing how the social shapes technology in a number of different ways. The shift in the focus of analysis from economics to sociology has also been characterised by a determined attempt to prize open the black box of technology - an approach which is concerned not only with social influences on technical change but with the social character of technology itself - has gathered momentum. This approach to technology study can be characterised by three trends in the sort of analysis attempted. Firstly, an attempt to move away from the individual inventor or 'genius' as the central explanatory concept. Secondly, it involves a rejection of any form of technological determinism, and thirdly, it attempts to remove the distinctions between technical, social, economic, and political aspects of technological development. This is characterised by the "seamless web" of society and technology. (Bijker et. al., 1989)

Bijker et. al. (1989) seek to prise open the black box of technology. Following MacKenzie, D. and Wajcman, J. (1985), they identify three layers of meaning of the word 'technology'. Firstly, the level of physical artifacts: bicycles, lamps, and bakelite. Secondly it may refer to activities or processes, such as steel making or moulding, and thirdly it may refer to knowledge: what people know as well as what they do; e.g. the 'know how' that goes into designing a bicycle or an ultrasound device in the obstetrics clinic and they identify three main approaches to the study of technology.

The social constructivist approach is rooted in the attempt to apply the insights gleaned in recent studies in the sociology of science. Its key concepts are "interpretative flexibility", "closure", and "relevant social groupings". One of the central tenets of this approach is that technological artifacts are open to sociological analysis, not just in their usage, but especially with respect to their design and technical "content". This approach places emphasis on "thick description": getting inside the "black box" of technology (or society). This results in a wealth of detailed information about technical, social, economic and political aspects of the case under study. In order to make sense of this complexity it is necessary to employ some structuring and simplifying concepts. They lay out their stall with a discussion of the 'Empirical Programme of Relativism' (Collins, 1981), the Social Constructionist approach to the study of technology followed by an attempt to produce a synthesis of the two approaches.

The starting point for the sociology of science is the claim that all knowledge claims are treated as socially constructed. The approach wishes to chart or reconstruct the processes whereby knowledge is validated in the social domain. A number of different empirical programs have been generated, for example Woolgar's (1982) study of the laboratory bench, and Collins (1981) focus on scientific controversy. The significance of these studies is the suggestion that there is nothing epistemologically special about the nature of scientific knowledge.

SCOT is critical of existing historical approaches which tend to be descriptive and utilise a fine detail approach which shows little concern with generalising beyond specific historical instances. A second problem is that such studies tend to focus overwhelmingly on successful innovations. Pinch and Bijker allude to the fact that in twenty-five Volumes of "Technology and Culture" only nine articles were devoted to the study of failed innovations (Staundenmaier, 1985). The SCOT approach draws on the ideas of Bloor (1976) who advocates the use of a 'symmetry principle' which holds that both true and false beliefs (or, in this case successful or failed technologies) are to be analysed in the same terms. This is because, as Noble's work above has demonstrated, the logic of success or failure is a social as opposed to technical achievement.

As we have seen sociological approaches tend to apply Kuhn's theory of paradigms to the study of technology. This, they argue does represent an improvement on standard descriptive histography, but it is not clear that Dosi shares the commitment to the social construction of technology and neither does he employ a symmetrical approach to the study of both failed and successful artifacts. Further by locating the discussion at the level of technological paradigms it is not clear how the artifacts themselves are to be approached. What is needed, they argue, is an empirical programme of research.

In this endeavour they draw on the 'Empirical Programme of Relativism' which, they argue, can be distinguished from other approaches by the focus on the empirical study of contemporary scientific developments and the study, in particular, of scientific controversies. Three stages in the explanatory aims of EPOR can be identified. Firstly, the 'interpretative flexibility' of scientific findings is displayed which demonstrate that scientific findings are open to more than one interpretation. This represents a shift in the focus of explanation for scientific developments from the scientific world to the social world. Secondly, interpretative flexibility is assigned limits when a consensus emerges and controversies are terminated, and thirdly these closure mechanisms are related to the wider social milieu. Once a consensus is reached the interpretative flexibility disappears and becomes hidden from view.

The social constructionist school attempts a similar approach. The developmental process of a technological artifact is described, in keeping with Dosi, as an alternation of variation and selection. But in contrast to Dosi the linear nature of the relationship between science and technology and of technological change itself is rejected in favour of a 'multi-directional' approach. Central to this model is the insight that 'successful' stages, which are usually identified retrospectively, are not the only possible ones. Nor are they guided by a purely technical logic.

This is illustrated through the use of the bicycle as a case study. Pinch and Bijker are anxious to break with models which might see the development of the bicycle in terms of a rational, linear process in which a clear line of development e.g. boneshaker - Penny Farthing - Lawson's Bicyclette can be drawn with other variations represented as amusing aberration which do not need to be taken seriously.

Such models tend to reinforce views of resourceful engineers inventing solutions to technical problems. In reality the process is a much more complex one in which different relevant social groups (e.g. women cyclists) identify specific problems (e.g. problem of dresses and high wheelers). At any given moment several solutions to defined problems can be identified. The 'successful' solution emerges over a period of time and the artifact stabilises.

> "By using the concept of stabilisation, we see that the 'invention' of the safety bicycle was not an isolated event (1884), but a nineteen year process (1979-98).

> For example, at the beginning of this period the relevant groups did not see the 'safety bicycle' but a wide range of bi- and tricycles- and, among those, a rather ugly crocodile-like bicycle with a relatively low front wheel and rear chain drive. By the end of the period, the phrase 'safety bicycle' denoted a low wheeled bicycle with rear chain drive, diamond frame, and air tyres. As a result of the stabilisation of the artifact after 1898, one did not need to specify these details: They were taken for granted as the essential 'ingredients' of the safety bicycle."
>
> (Pinch and Bijker, 1989: 39)

The solutions which emerge out of this process of stabilisation are not only technological ones but also judicial or even moral ones (e.g. changing attitudes toward women wearing trousers).

They insist that they wish to avoid a retreat to statements about 'consumers' and 'producers' as such an explanation would be possible but would entail closing the black box. In order to open it up the authors call for a "detailed description" of social groups.

They then go on to attempt to link SCOT and EPOR by showing how the key concepts can be shared. The application of the concept of 'interpretative flexibility' would entail demonstrating that technological artifacts are socially and culturally constructed. The idea is to show that there is flexibility not only in the way people think about, or interpret an artifact, but that there is also flexibility in the way that artifacts are designed. The example of the bicycle is raised to demonstrate this. They argue that it is the meaning given to high wheeler as 'unsafe' for women and elderly men as opposed to a 'high speed' bicycle which impacted upon the design rationality that produced the stabilised artifact.

They identify two forms of closure. Firstly, rhetorical closure in which stabilisation and closure occur when all the problems are perceived to be solved by relevant social groupings. They give the example of the attempt to close the "safety controversy" through the use of advertising as opposed to the development of technological solutions. They do not explain why this attempt should have failed.

Secondly, closure by redefinition of the problem. The example the authors use to illustrate this mechanism is the translation of the air tyre from a solution to the vibration problem of low wheelers to the solution to the quite different problem of how racing cyclists could go faster. This translation effectively produced closure for two relevant social groups: racing cyclists and the general public.

It is argued that SCOT, in relation to the wider context, may have a point of entry not available to EPOR. The method of describing technological artifacts by focusing on the meaning given to them by relevant social groupings would seem to suggest that the socio-cultural - political context of a group shapes its norms and values, which in turn influence the meaning given to the artifact.

> "Because we have shown how different meanings can constitute different lines of development, SCOT's descriptive model seems to offer an operationalisation of the relationship between the wider milieu and the actual content of technology."
>
> (Pinch and Bijker, 1989: 46)

Bijker (1989) follows this thread. He seeks to develop the SCOT perspective outlined by Pinch and Bijker in a case study of the social construction of Bakelite. The concept of 'interpretative flexibility' is elaborated upon and two new concepts are introduced: 'technological frame' and 'inclusion'.

A perceived scarcity of natural products like ivory and rubber acted as the spur for the development of synthetic alternatives. Two rival plastics, Ivoride and Celluloid were developed and the selection process was determined largely by a patent controversy. Bijker argues that the debate can be used to demonstrate the interpretative flexibility of the artifact celluloid.

He describes the interpretative flexibility of the artifact as really being three artifacts - an embryonic plastic material, a potential dye yet to be analysed, and a method for studying natural resins. However it is not until the turn of the century that the first artifact came into existence. Bijker is concerned to answer the question why it was that the first artifact, Bakelite as it came to be known, was not discovered earlier.

One explanation is the high cost of formaldehyde but the development of cheap formeldehyde did not lead to the development of commercial plastic. He suggests that to argue that "they just didn't see it" is merely a restatement of the problem, what is it that prevented synthetic plastic becoming an issue for this a community of chemists? To explain this he uses the concept of a 'technological frame'.

> "A technological frame is composed of, to start with, the concepts and techniques employed by a community in its problem solving. Problem solving should be read as a broad concept, encompassing with it the recognition of what counts as a problem as well as the strategies available for solving the problems and the requirements a solution has to meet. This makes a technological frame into a combination of current theories, tacit knowledge, engineering practice (such as design methods and criteria),

specialised testing procedures, goals, and handling and using practice."

(Pinch and Bijker, 1989: 168)

It is not just that the community of chemists were interested in different things - synthetic dyes, Bijker argues that making plastic by chemical synthesis *could* not occur to them. Neither chemical theory nor chemical practice at the time could not cope with such a substance. Baekeland was able to make the leap because of his low level of inclusion in the frame and his inclusion in another frame - electro-chemical engineering so he did not get stuck in the problem solving strategy.

Bijker's scheme is very similar to Kuhn's but he does attempt to differentiate what distinguishes a social constructivist account from Kuhn's and that is the 'broad', nature of the concept. It includes not only engineers but also other interested groups and also that a technological frame is intended to apply to the *interaction* of various actors. It does not refer to individual or systemic characteristics. Frames, he argues, are located *between* actors, not *in* actors or *above* actors. He likens this to Callon's (1986) concept of networks. A technological frame is built up when interaction around an artifact starts and continues. In this sense the artifact plays a role that is similar to Kuhn's exemplar.

More than one frame may exist at any given time and three situations are distinguished to characterise the developmental process of an artifact at some stage. Firstly, where there is no dominant technological frame e.g. the bicycle around 1880, Secondly, where there is one technological frame - Kuhn's normal science e.g. synthetic plastics 1880 - 1920, and thirdly where there are several dominant technological frames, e.g. -uses Hughes account of ac - dc electrical systems (1983, 1989). Each phase is characterised by different types of variation, selection and stabilisation processes. In the third instance rhetoric becomes the selection mechanism.

It is clear that the social constructivist 'school' is broad and, despite considerable overlap, contains a number of distinct positions. In the face of this diversity Bijker (1993) has attempted to pull the various threads together into a coherent theoretical project. He identifies three major issues facing the SCOT approach: relativism, reflexivity, and the need for theoretical coherence.

He is rather summary in his dismissal of the first two. In respect of the problem of relativism he makes the distinction between ontological/epistemological relativism and normative or political relativism. The former refers to issues of methodology and has been targeted by critics like Woolgar and Grint (1991, 1992). The latter to the effects of technology e.g. surveillance, control and deskilling and issues around the democratic control of technology (Russel, 1986; Winner, 1993). Russel suggests that the former implies the latter but Bijker rejects this and differs to Voltaire's reaction to the same accusation

> "..when he was accused of letting all norms and values be eroded because he proclaimed that God did not exist...the fact that God is dead did not mean that everything was now allowed- it only meant that things were not allowed for reasons different from biblical reasons"
>
> Bijker 1993: 116-117)

This retreat to liberalism also characterises Elam's (1993) defence of Woolgar but, in my view it obscures more than it reveals.

The problem of reflexivity, of course, leads to the circular problem of building general accounts of knowledge that deny that very possibility.

Bijker denies that this makes general theory impossible and summarily dismisses the problem and assigns reflexivists, like Woolgar, the role of "court jester" (116). He identifies the problem of theory as the most pressing one as there are mounting claims that the continuing build up of empirical case studies is facile in the absence of a coherent general theoretical framework in which to locate them. Bijker states the problem thus

> "So, is our state in despair? Are the problems of relativism and reflexivity stifling our movements...or is the problem of theory turning our endeavour into a mere storytelling and thereby into a far less ambitious project?"
>
> (1993: 117)

He dismisses the problems of relativism and reflexivity and focuses his attention on theory.

Bijker argues that all the elements for a coherent theoretical framework exist and it is just a matter of pulling them all together. The key features that a theory needs to incorporate, he argues are: first the 'seamless' character of the 'web of technology and society'; second the mechanisms for continuity and change; and third the nature of the tension between actors and structure. Such schematics are common in sociological theorising but he might also have included a fourth axis of conflict/consensus as for example Burrel and Morgan (1979).

He addresses these in turn. The first element entails a need to recognise technical change as an inherently social process with contingent outcomes. At a conceptual level he draws on the ideas of 'relevant social group' and 'interpretive flexibility', which are demonstrated by means of the case study of the bicycle. Second, the issue of technical continuity and change is discussed through the concept of 'technological frame', which is illustrated by the case study of Bakelite. Bijker likens this to Hughes' notion of 'systems' and Law's notion of 'translation' in actor network theory. Together with concepts like the 'seamless web' (Hughes, 1989) and 'heterogeneous engineers' (Law, 1987), he argues that these go some way to providing a sociological account of technical change that avoids the problem of technological imperatives or determinism. Third, he draws on the case study of the fluorescent lamp to argue the need to shift 'technical artifacts' as the unit of analysis' to 'technological ensembles'.

The contingent nature of technical change raises an important question, how are limits to be ascribed to this process? Given interpretive flexibility, heterogeneous engineers seem capable of sending history off in any direction. The problem, as he sees it, is although social constructionism can clearly account for technical change can it, at the same time account for technical constancy or continuity?

Bijker attempts to resolve this problem by extending the concepts of "stabilisation" and "closure" and he makes an interesting distinction between these two concepts. Closure refers to the point when all controversy is ended and consensus concerning the 'nature' of an artifact is reached. At the same time

> "As soon as consensus emerges, the interpretive flexibility of scientific claims ceases to exist, and Nature is invoked as the cause of consensus and not a result......It is important to realise that, consequently, this process of closure is almost irreversible"
>
> (1993: 121-122)

Stabilisation, on the other hand can occur in varying degrees depending upon the level of consensus in and between relevant social groupings. This distinction is forwarded in order to overcome the problem, inherent in the idea of interpretive flexibility, that anything is possible or that any configuration of artifacts and social groups can be built or broken down at will. This is the often cited Achilles heel of ethnomethodological approaches to the social such as Woolgar's that larger structural elements are ignored. Bijker recognises the limitations of this and he argues that such a theory of technology proposing such a view of our technological society greatly underestimates the solidity of a society and the stability of technical artifacts. Thus structural environments do exist at varying degrees of stabilisation or closure and this serves to limit choice.

Bijker uses the concept of the "technological frame" to bring these elements: seamless web, structure/action, change/continuity. Also, a technological frame is a dynamic as opposed to a fixed entity as they are established as part of the stabilisation process. Drawing on an almost Durkheimian formulation the technological frame is seen as both above and within individuals.

> "A technological frame does not reside internally to individuals or externally in nature - a technological frame is largely external to any individual, yet wholly internal to the set of interacting individuals in the relevant social group. Thus the technological frame needs to be continuously sustained by interactions."
>
> (1993: 123)

Third, a technological frame provides the

> "goals, thoughts, and the tools for action. They enable thinking and action like Wittgenstein's (1953) "forms of life". A technological frame offers both the central problems and the related strategies to solve them...but at the same time the technological frame will constrain the freedom of the member of the relevant social group"
>
> (1993: 123)

It seems to me that the distinctions that Bijker is making between "paradigms" and "technological frames" is a little artificial. He appears to be using it to describe a different moment in a similar process of change. For example, the notion of paradigm refers to a period of "normal science" following the formation of strong consensus or closure. A technological frame, on the other hand, includes a prior period of uncertainty and agitation leading to revolution. Even the claim that the technological frame is more heterogeneous is open to some dispute as it is clear that members of the none-scientific community have always been mobilised in an attempt to establish the veracity of scientific claims. For example, Boyle invited members of the aristocracy to witness his experiments to shield them from ridicule or criticism. Thus it is clear that paradigm formation is a highly political and heterogeneous process.

It is significant that by 1993 Bijker has recognised the need to extend the notion of environment and the forces shaping technology are much wider than pluralist activities of a few 'relevant social groups, and this is why he introduces the notion of "socio-technical ensembles". In this case study he moves beyond the pluralist activities of relevant social groups and suggests that the sociological study of the fluorescent lamp leads to the study of patent economics, firm organisation, economics of innovation, and society at war.

> "The 'stuff' of the invention of the fluorescent lamp was economics and politics, as much as electricity and fluorescence."
>
> (1993: 124)

He calls to for an extension into general sociology and he argues that the technical and the social are not the same but are inseparable.

> "A landscape of sociotechnology unfolds. All relations are both social and technical. Purely social relations are to be found only in the imaginations of sociologists, among baboons, or possibly nudist beaches; and purely technical relations are to be found only in the sophisticated reaches of science fiction..... the technical is socially constructed, and the social is technically constructed - all stable ensembles are bound together as much by the technical as by the social. Where there was purity, now there is heterogeneity. Social classes, occupational groupings, firms, professions, machines - all are held in place by intimately linked social and technical means."
>
> (1993: 125)

He goes on to say that this situation is different from the one discussed in his bicycle case as a principle of general symmetry has replaced a principle of symmetry; technical artifacts are replaced by sociotechnical ensembles as the unit of analysis. This is a clear recognition of the limitation of a focus on artifacts which, as I will argue below, is unable to capture the indeterminacy of computer based systems which need to be located in a much broader social context than the notion of relevant social groups permits. The principle of symmetry (Bloor, 1976) advocates that all true and false beliefs (successful and unsuccessful technologies) be analysed in the same terms. The general principle of symmetry (Callon, 1986) extends this to say that the construction of science and technology and the construction of society should be analysed in the same framework

> "...and the sociology of technology seems to move imperialistically into the domain of general sociology"
>
> (1993: 125)

Once again, he uses the language of Durkheim to state his case when he argues that the sociotechnical ensemble is not merely an intimate combination of social and technical factors; it is something sui generis. This is interesting because what he is calling for is a sociology committed to the totality; one in which every component part can only be understood in terms of the whole. This is all very familiar in the history of sociology but he does not really provide clear clues as to how this ambitious project is to be realised. It seems to me that Bijker is struggling to expand the focus of SCOT to include the kind of considerations of broader understandings of power influence on technology that were outlined above in the social shaping school.

Bijker, then, has attempted to provide a theoretical framework for explaining technical change that addresses the key issues of technology and technical change as a social construction, that explains both change and continuity and locates actors in a broader structural setting.

Summary

Classical accounts are anchored in discourse of progress which emphasises the rational nature of the technological enterprise. Over a long period this discourse has been dismantled. Schumpeter made the process of technical change less predictable and Nelson and Winter diluted the commitment to human rationality by locating technological understanding in routinised behaviour. Dosi extends this idea to using the Kuhnian notion of paradigm, and technological trajectory to show how technology takes on a momentum of its own. However, in doing so, he maintains the linear logic of earlier theorists and underestimated the influence of actors upon the environment. Hughes goes a stage further by showing how the distinction between technical system and environment is an artificial one. In reality 'system builders' have focused energy on a whole range of problematics beyond the simply technical.

Hughes, then, expands the technical paradigm to systemic status but still isolates it to the concerns of the system builder. This is the point with which MacKenzie and Wajcman take issue when they show how different interpretations of same 'reverse salient' are possible, and how different interpretations are tied to the interests of competing parties. In the final analysis it seems that Hughes model suffers from the same problem of constituting technology as 'autonomous' as does Dosi's. This very point is picked up by Social Shaping approaches that demonstrate that technological logic is subject to other guiding logics, for example in Noble's case the logic of control. Pinch and Bijker take this insight to an extreme position. For them, not only is technical change the product of social, as opposed to technical, negotiation, so too is technological content. Law attempts to temper this view by showing how the social and the technical should be thought of as different elements in a single network.

Social constructionist accounts have been criticised for narrowing the focus of analysis to the activities of a few relevant social groupings. Bijker has gone some way to address the limitations with his notion of socio-technical ensembles and Callon, too, shows how technical and social dimensions of artifacts and processes cannot be separated - technical development is tied to specific views and understandings of social development so that the distinction between technology and society, or technologist and sociologist, is an artificial one. Callon provides us with one of the most insightful accounts of the way in which technology is subject to discourses of modernity. Callon's approach is interesting but it could be argued that what the engineers were doing was not sociology, as he suggests, but generating discourses which legitimated the ideas and interests they were pursuing. Indeed Callon's approach lends itself to this extension - the nature of technology is a product of wide social discourses. What is now needed is for this insight to be extended to show that discourse does not only impinge upon technology, but also to explore the degree to which technology is constituted in and by discourse.

CHAPTER 8

The Social Construction of CAPM

In my view the SCOT framework is a useful one for understanding the nature of CAPM, although, as will be become clear, it also suffers from limitations. In this section I will apply, and examine the limits of, the concepts of relevant social group, interpretive flexibility, stabilisation and closure, technological frame and technological ensemble to CAPM.

CAPM: Interpretive Flexibility and Relevant Social Groupings

In chapter 4 a view of CAPM was presented that was drawn from definitions in the literature on production engineering. In this perspective CAPM is defined in terms of the objectives it is intended to achieve, the functions it is intended to perform, and the level of integration, both technical and organisational, that is achieved. This definition tends to construe CAPM as an objective entity, albeit a complex one, that is brought within the boundaries of an organisation and then integrated into the daily routines and processes of organisational life, and this dovetails neatly with Rogers' account of the process. However, this kind of definition tends to underestimate the 'indeterminateness' (Woolgar, 1991) of the technology and the degree to which the very *nature,* as well as the use of CAPM is context specific. Clearly technical definitions of this kind do recognise the complex nature of CAPM 'systems' and the degree to which they can be disaggregated and combined in different ways to meet varying technical and organisational requirements, although this is ultimately reduced to the 'principles of production engineering' (Corke, 1985: 6). It is a view of CAPM that sees it as a system, or sets of potential systems, who's content varies according to the requirement and degree of sophistication. This is one way in which CAPM is indeterminate but it is still subject to limitations because this indeterminateness stems from the technical and functional roles allocated to different software modules and this amounts to an objectification of CAPM that is highly problematic.

The concept of interpretive flexibility enables us to move beyond these limitations in understanding CAPM to see the way in which the nature of CAPM cannot be understood in terms of the internal characteristics of the 'technology itself' but in the social activities in which it is constituted.

We can explore the interpretive flexibility in two ways. As we have seen, the controversy prior to the stabilisation of an artifact is the key period in which interpretive flexibility can be seen. In respect of CAPM there are two aspects to the controversy which will help us. The first concerns the relationship between CAPM and MRPII systems and the second the long running controversy over the relationship between MRP based systems and JIT systems[1].

In respect of the first part of the controversy the question that arises is what is the difference, if any, between MRP(II) and CAPM, and what is the significance of the different nomenclature? This is important because it is suggestive of the fact that CAPM (MRPII) systems are still in the process of development and have not yet reached a point of stabilisation. The first task, then, is to attempt to understand CAPM dynamically in

1 JIT refers to the Just-In-Time approach to production developed in Japan. The nature of JIT will be examined in detail later in the chapter. The debate, outlined below, is centred on the controversy about whether or not the two systems are compatible.

terms of its evolution. The argument forwarded is that the idea of CAPM is one moment in a long process of the development of what I will refer to as MRP based systems, and that it represents an attempt by academics and experts to assign limits or boundaries to a technology that is so amorphous that it is very difficult to pin down. In my view this attempt did not succeed and so in the course of this chapter I will use the term MRP based systems to refer to CAPM.

The second aspect of the controversy revolves around the relationship between CAPM (MRPII) systems and JIT systems. There is an important tension between the two that can be observed in two ways: first in the struggles of the organisations studied in attempting to 'make sense' of them and incorporate them both into their organisational environments, and second, in the long running controversy in the production engineering literature on the 'push- pull' debate which centres around the compatibility or otherwise of these two approaches. This is important because it throws into relief the degree to which CAPM systems, both in theory and practice, are subject to discursive construction. If this is the case then definition is not simply a descriptive exercise but cuts to the heart of the CAPM problematic. It also tests the limitations of the concepts of stabilisation and closure as I will argue that stabilisation is highly problematic in the context of software based manufacturing systems as, in a sense, the technology is 'always becoming'. This means that the view of interpretive flexibility in the design and production stages of an artifact leading to stabilisation in use may have to be revised in the case of computer technologies as interpretive flexibility continues in use as well and stabilisation can only be regarded as either arbitrary or local. Also I will go on to argue that the problem can only be resolved by an understanding of technology that sees it as constituted in discourse. Thus the JIT/MRP debate throws into sharp relief the way in which technological artifacts are the embodiment of ideologies or discourses.

In the following section I will address the first aspect of the controversy through a review of the development of CAPM/MRP based systems.

CAPM as a mushrooming technology: From MRP to MRPII to CAPM and beyond

At first sight it may seem that the two terms, CAPM and MRP(II) are simply different labels that refer to the same technology, and indeed it was clear from early interviews with production engineers that there was a great deal of uncertainty surrounding this distinction, but the question still arises where did the term CAPM come from and why? It is apparent from the case studies that CAPM was not a term in common parlance and subjects invariably talked of their systems as MRP(II). Further, in exploring the literature on the types of technology in question the term CAPM hardly occurs at all, and again MRP(II) is almost exclusively deployed. This is very relevant for the analysis of the technology, and issues around its adoption, because to understand this discrepancy in nomenclature it is necessary to take a geneological approach to defining it. That is to explore the conditions by which the CAPM label arose and the interest groups (relevant social groupings) associated with it. The view I forward here, is that the distinction arose as a result of problems of the interpretive flexibility of the technology in question and represents an attempt, by professional engineers and academics, to deal with ambiguities and uncertainties associated with MRP based systems.

The production engineering literature contains a number of accounts of the development of MRP (Melynk and Gonzalez, 1985; Galvin, 1986; Daniels, 1986; Millard, 1985) and these are all derived, in large part, from Wight's account (1981). The MRP story begins with the crisis experienced by western economies, and particularly the United States from the late 1960's. This became a focus for many commentators

> "Since the late 1960's, America's economy has been slowly unravelling. The economic decline has been marked by unemployment, mounting business failures, and falling productivity."
>
> (Reich, R.B., 1983)

The 1970's could be characterised as a period when material and energy costs were soaring. Competition from the Pacific Rim was emerging, notably in the form of Japan, and there was a crisis of confidence in the quality of products in the form of poor design, poor manufacture and poor service.

The solution to these problems arrived in the form of a computer package that would, it was claimed, 'revolutionise' American productivity. During the 1970's APICS (American Production and Inventory Control Society) ran a campaign promoting MRP (Material Requirements Planning) and it has been estimated that approximately 8000 firms attempted to implement MRP systems during this period (Melnyk and Gonzalez, 1985). This was to be the beginning of a process that has continued through the 1980's as the technology for production control began to expand along with increasing hype from both professional groups like APICS and suppliers.

Materials requirement planning is not a new idea. Its origins lie in gross requirements planning which was a simple method of planning that involved determining how many components were needed to produce a given end item quantity. Given that such plans could easily be upset by a short fall in components, early planners approached the problem through the maintenance of an inventory. This, in turn, generated a need for a method of control over material ordering. The problem was solved through the development of order point/order quantity (Millard, 1985) entry systems which launched work and purchase orders for predetermined quantities once inventories fall below a set level. The problem with this system was one of balance as orders were not related to requirement, only inventory level, thus leading to problems of stock out and overstock.

This mismatch between requirement and inventory led to the development of MRP: a series of computer programs designed to match material requirement with inventory levels thus keeping requirements and inventory replenishments in balance. The solution to the problem of material availability served to highlight further problems of manufacturing scheduling, for example labour, tooling, machine availability. The limitations of MRP in controlling manufacturing was offset with the development of the "closed loop MRP".

Closed loop MRP systems were designed to cope with the problem of unrealistic master production schedules by means of a feed back control loop which would enable comparisons to be made between manufacturing work loads and actual capacity thus facilitating contingency planning. In essence closed loop MRP is MRP plus a capacity planning capability.

If closed loop MRP systems provided a labour and equipment dimension to MRP then the next development, MRP-II (Manufacturing Resource Planning) provided a financial dimension which could express manufacturing plans in cash terms and, in later systems, provide a simulation capability to evaluate the impact of pursuing various alternatives.

This schematic representation of the evolution of "MRP" systems reads more smoothly and chronologically than the actual process. In reality there has not been a linear development with one form becoming obsolete with the arrival of another. A plethora of systems exists side by side often with various labels, e.g. MRP, MRP-II, Manufacturing Resource Planning, and latterly CAPM, and a great deal of confusion surrounds their precise nature. One commentator (Millard, 1985) has noted that some companies do not require the multi-assembly level explosion capability of MRP. In other words, their 'Big MRP' system does not even contain an MRP module. Millard is drawing our attention to an important point: that "big MRP" thinking is out of synchronisation with the development of computer systems in manufacturing over time that have taken 'MRP' out of the closeted realm of production, and further, that both

> "..closed loop MRP and MRPII focus undue attention on MRP which, in many ways, is not the most important module in the manufacturing side of MIS."
>
> (Millard, R., 1985: 28)

The process is by no means over. Each new solution carries with it its own particular problems and provokes awareness of other possibilities particularly in the area of system integration. A whole series of developments (or visions) are floating around. For example: the old image of MIS as system of monthly financial reporting has given way to a new understanding based on the recognition that the interaction of all a company's reporting and control systems can generate a comprehensive information package (Executive Information System [EIS], which will facilitate greater management control and co-ordination (Jain, 1991; Parker, 1994); EDI electronic data interchange (Green et. al., 1992; Vasilash, 1992); integration with CIM (Computer Integrated Manufacture) (Kessler, 1991).

The interpretive flexibility of MRP based systems is evident in the confusion over the identity of MRP based technologies and this finds its expression in the literature in the emergence of a whole series of articles from the mid to late 1980's in which definitive definitions are attempted and range from a computer application system (Aggarwal, 1985), a complete manufacturing control system (White, 1986), a philosophy of business management (Raynor, 1987a), a complete management information system (Millard, 1985), a communication system (Galvin, 1986), and there is also a recognition that what MRP based systems are varies greatly from company to company and environmental context (Daniels, 1986).

Amidst all this confusion, the term CAPM arrived on the scene and appears to have been related to a government initiative to promote the use of computers in manufacturing industry. In September 1984, The Science and Engineering Research Council (SERC) and the Department of Trade and Industry (DTI) launched a major initiative on the application of computers to manufacturing engineering (ACME). A year later in 1985 Corke published his book "A Guide to CAPM". In 1986 the ACME Directorate commissioned a survey of CAPM usage which was published in 1987 (Monniot et. al.) and this was followed by a great deal of research activity in the area. Interestingly, the label CAPM seems not to have survived the initiative and it hardly shows up at all in a search of the literature from 1980 -1995. When it does it is usually related to one of the groups commissioned by ACME to conduct investigations (e.g. Clark and Staunton, 1989; Newell and Clark, 1990,1993; Swan and Clark, 1992; Bessant and Buckingham, 1993, Webster, 1991,1993). The term used almost universally, to refer to such technologies remains MRP(II). The point is that CAPM can be seen as an attempt to influence the stabilisation of MRP based systems by defining its boundaries. However this attempt was not successful. According to Clark and Newell (1993) this may be because BPICS (British Production and Inventory Control Society) were never, in Callon's terms, enrolled by ACME.

It is interesting to note that in an interview conducted in 1989 Corke revises his definition of CAPM to a much more amorphous one and provides the following understanding

> "I'd say CAPM is a name like gardening. Gardening has in common that people dig the soil and make things grow. Whether they grow vegetables or flowers or just not flowers or what. It's just sort of a general area"
>
> (Interview 1989)

The above account of the development of MRP(II) is highly rationalistic in that it presents the development of MRP(II) as a linear, step like sequence of, in Rogerian terms, performance gaps and solutions. However, it does help to describe the way in which the technology has 'mushroomed' taking on more and more roles and functions.

It is clear from the case studies that the images of the computer systems, as system implementation took place on the ground, was continually shifting as new possibilities were perceived. So at BritCo just as they felt they had tamed the beast news arrived that a new system was to be introduced uniformly across all subsidiaries. What had started as a production control system was now set to develop into a centralised management information system. At PlastiCo too, despite the failure, plans were already a foot to introduce the next system which would also be uniform across the operating companies. The nature of the computer based system leaves it open to constant redefinition.

Although the above account is useful it obscures the degree to which the process has been driven by particular interests and constitutes part of a broader industrial vision. Cork's comments above hint at this and it is clear to me that MRP based systems represent an embodiment of paradigmatic commitment of American production engineering and an enduring commitment to technical, as opposed to human solutions to problems of the organisation and control of industrial production, and this provides the technological frame in which MRP based systems are located.

From the early 1970's when the first MRP systems were adopted and implemented by a few leading American companies, MRP has, in some twenty five years, managed to 'imperialize' a great deal of manufacturing industry. This period can also be characterised as a crusade on the part of APICS to promote MRP systems (Kanet ,1988): by 1986 the membership has swollen to over 61,000 members and 16,000 certified practitioners, who have demonstrated a knowledge of MRP methodology. Orlicky (1975) estimated that there were 700 companies using MRP based systems in the US. and Wight (1981) says that this figure had risen to around 8,000. by 1981. Kanet (1988) estimated that in 1988 there are probably at least 700 consulting firms and software houses "homilizing the virtues of MRP" (57).

However this enormous activity, hype, and growth has been accompanied by a great deal of doubt concerning the real benefits of MRP based systems (Lincoln, 1986; Raynor, 1987a; Brady, 1988; Sheridan, 1989; Schuelke, 1992).

MRP: Visions and Realities

MRP based systems have been promoted by suppliers and professional groups as a technological solution, based around computers, to the problems of industrial efficiency and profits. For example, Wight (1981) subtitled his highly influential text on MRPII "Unlocking America's Productivity Potential" and Orlicky (1975), in what must be seen as the classic MRP text states

> "The breakthrough, in this area, lies in the simple fact that once a computer becomes available, the use of such methods [traditional] and systems is no longer obligatory. The new computer-aided methods of planning and controlling manufacturing inventories made the true interrelationships and behaviour of items constituting these inventories highly visible, thus eliminating the tenuousness of many previous assumptions and revealing the causes of inadequacies (always admitted) of many traditional methods."

The aim was to produce a computer system that would control the manufacturing system by means of a centralised data base. Noble has already shown how the development of industrial technologies in the U.S. have been shaped by an idea of 'the workerless factory', and the computer was to have centre stage in a process of data driven automation in which

> "Quality control is maintained by computer sensors measuring production continuously so that errors and deviations will be corrected as soon as they occur. One pictures the Japanese manless factory with only two employees, a man and his dog - the dog guards the factory and the man feeds the dog."
>
> (Groves, 1990: 60)

In practical terms MRP promised to reduce inventory levels and improve service to customers. Wight (1981) talks of typical inventory reductions of 20-35%. However the evidence suggests that MRP has not fulfilled its promise. For example Kanet (1988), charts inventory turns in the US manufacturing sector between 1948 and 1986. These figures show that although there is some improvement since the early 1970's that this is better explained in terms of the cyclical nature of the economy as every low point in inventory turns, correlates with the low points of economic recession. Likewise inventory improvements appear to follow up turns. Of course, this explanation of the figures is speculative, but Kanet makes the impressive point that even if MRP was responsible for the measurable improvement between 1982 and 1986, inventory turns have still only returned to the level experienced in 1950! (Kanet, 1988: 57-58).

Yet the commitment to MRP based systems by APICS remains strong and the response to the widely recognised problems with MRP based systems has been to place the blame not on the technology but on its poor implementation and use. We have already noted that Corke (1985) has identified the problems as being *only* either the adoption of an inappropriate computer system, or that the management is not applying the principles of production management appropriately. Other problems identified in the literature are: inaccurate data records (Burker, 1988; Ross, 1989); poor implementation (Safizadeh, 1986; Pendelton, 1987; Sheridan, 1989) unrealistic schedules (Sheridan, 1989); lack of top management involvement (Whiteside and Ambrose, 1984; Rao, 1985); lack of performance measurement (Burker, 1987; Neeley, 1989) and lack of education (Potter, 1988; Burker, 1988; Cerveny and Scott, 1989). It is interesting to note that these issues were well known to the actors involved in most of the case studies. For example at PlastiCo all of these issues were addressed and yet still the result was a computer system that did not work.

Yet despite numerous articles identifying such problems and recommending solutions MRP systems continue to perform poorly (Galvin, 1986; Kanet, 1988; Clode, 1993). Various problems have been diagnosed and solutions forwarded and what most have in common is a commitment of finding new ways of making it work. For example, in a striking example to the commitment to a technological frame, after producing a forceful critique of the state of MRP based systems, and a review of the various remedies that have been tried and failed, Kanet (1988) shifts the goal posts again by concluding with a call for more computing power: the problem is not the user, nor the software, now it is the hardware. The technical fix again wins the day and Toffler is paraded to demonstrate the need for more not less technology

> "MRP-based logics was designed for use on third generation computers of the 1960's whose processing speeds were measured in microseconds. Today computers are 100 times faster, and fifth generation computers, which are just around the corner, promise to be 100 times faster still. Yet the state-of-the art software that we have in manufacturing logistics does not come close to exploiting this potential"
>
> (1988: 60)

Like Orlicky before him, he sees the future as one in which new methodologies based in advanced computer technologies, in this case artificial intelligence, will rescue production in general and MRP based systems in particular, from their present malaise.

The SCOT approach then, allows a fluid understanding of CAPM that enables us to understand its 'indeterminacy'. On the other hand there are also some limitations to the approach, particularly in the context of software based systems, and the concepts of stabilisation, closure and relevant social group need close scrutiny.

Woolgar and Grint (1991) pick up the theme of the social dimension of technology and apply what they term 'more virulent arguments' from relativism-constructivism. Like Kling (1991) they emphasise that the way in which technology is used is equally as important as the manner in which it is produced.

For them SCOT is a limited brand of interpretivism which underestimates the continuing indeterminacy of technology in use. To explore this point further they make a distinction between two kinds of interpretivism. The first they refer to as 'restricted interpretivism'. For example, they are critical of the SCOT and Social Shaping approaches, because although these deny determinism in design and construction, they allow it following stabilisation. In these perspectives technical design embodies social choices and so technological artefacts can be understood as congealed social interests. The process of stabilisation represents a resolution of the various tensions that characterise the design stage and, with closure, the establishment of a consensus removes any doubt and ambiguity as to the character of the artifact and that is offered to the market.

The second, they refer to as a 'thoroughgoing interpretivism', and this stresses the continuation of flexibility in *use* as well as design and production. Woolgar and Grint problematise the concept of stabilisation by arguing that it is an arbitrary point in an ongoing process of interpretation and technological artifacts are always embedded in interpretive contexts and their nature always indeterminate. (Woolgar and Grint, 1991)

> "..what a computer is for, what it can do and achieve, is also regarded as an interpretive issue on any occasion that it is described, planned, talked about, marketed, sold, used, reviewed, dismantled and so on. These occasions can occur long before or after any point of stabilisation...technological artifacts can be construed as texts that are essentially embedded in (and at the same time constitute) their interpretive contexts"
>
> Woolgar and Grint (1991: 370)

This extension of interpretive flexibility from the design and production stages into use is illustrated by Kling. In a clear parallel with Cowen's (1983, 1989) studies of household technologies, Kling argues that too much emphasis has been placed on the production and dissemination of technology and not enough on the way it is consumed and he illustrates this point through a number of case studies. One is a case study of the implementation of a computerised 'urban management information system' in a welfare agency in an American city. The system was supposed to produce a number of benefits including reducing paperwork, increased managerial control and providing key data for needs assessment and programme evaluation. However Kling maintains that these and other claimed benefits never materialised. Despite this, the system was maintained and further large scale investment made. Kling goes on to argue that the systems primary value was in enhancing the welfare agencies' image when they dealt with federal funders and auditors.

> "Welfare administrators claimed that the federal staff from the Department of Health, Education and Welfare (HEW) saw them as more competent when they used computerised records rather than paper records."
>
> (Kling, 1991a: 348)

This resulted in a greater willingness to allocate federal welfare funds to the city and this was the system's primary value to the city officials. Here it is clear that the value of the computerised system could only be realised when harnessed to a persuasive discourse of efficiency and competence.

At BritCo the computer system continued to play second fiddle to the manual one largely because the managing director did not trust it and did not feel that the production process was well suited to computerisation, which in his view, was better suited to accounts. However, for him the computer system had another significance which the managing director referred to as the 'professional value' of the system

> "...professional because potential customers expect to come round and expect to see computerised production, so we gain from having modern offices, modern production facilities. You are not going to do that sort of thing and not have computerisation."

So for him then, the computer system was of great symbolic value as it served to establish the company's credentials as a modern and efficient organisation. That is not to suggest that that is all the computer was for, he clearly felt that it had aided efficiency even if he did not trust it.

For Grint and Woolgar (1991) this is a point of extreme importance. For them, the critical issue is not the technology itself but the interpretation of the technology. The implications of Kling's assertion that 'the computer system' is a "convenient fiction" is, to them, as clear as it is profound - the focus of analysis must be on the ways in which different fictions are produced and used - and this points to the need for a discourse analysis of technology.

> "..this is more than merely the study of the various ways in which technologies are labelled. By construing interpretive processes as primarily giving rise to 'labels', one mistakenly implies that the 'actual' technology pre-exists (or exists independently of) interpretive processes. By contrast, in recognising the constitutive function of interpretation, one accepts that the nature and capacity of a technology arises in and through the discourse of which it is a part."
>
> (Woolgar and Grint, 1991: 374)

The term discourse, in this context, is not synonymous with the way in which a technology is 'talked about' and Woolgar and Grint make a clear distinction between labelling and constitutive versions of interpretivism, as the former suggests that the technology pre-exists the discourse in which it is constituted, and this they do not accept. Nor is it a suggestion that 'talk makes reality' but refers to a more extended notion of discourse that includes structures of expectation, systems of categorisation, and modes of conventional practice. (1991: 377)

A second conceptual "narrowness' that Winner (1993) identifies concerns the conceptualisation of social processes in terms of 'relevant social actors' who are engaged in a process of defining, designing and reaching agreements and the problem with this is it tends to echo the political pluralism, of earlier sociology, that conveniently ignores issues of power.

> "Who says what are relevant social groups and social interests? What about the groups that have no voice but that, nevertheless, will be affected by the results of technological change? What of the groups that have been suppressed or deliberately excluded? How does one account for the potentially important choices that never surface as matters for debate and choice?"
>
> (1993: 369)

Winner is thinking of the way in which dominant logics operate through technology. For example, he argues, how thoroughly the interest and perspective of labour have been eliminated as a focus of any serious concerns on the development of manufacturing technology. A strength of SCOT is that it has managed to avoid linear, inevitable, Whig theories of history but it nevertheless has a blind spot when it comes to the operation of power in determining which groups are relevant and which are not. It seeks to avoid determinism and yet in also attempting to avoid extreme contingency (E.g. Bijker, 1993) little attention is given to the deep-seated political biases that can underline a whole range of choices made by relevant social actors.

Winner is drawing on a perspective that emphasises the way in which power relations in society find their expression in technical artifacts which he demonstrated in his case study of bridges as concretised inequality, but what is important is that this perspective concentrates the focus on the fact that in the process of interpretive flexibility not all actors have an equal voice. On the other hand, the weakness of Winner's perspective is that he does not adequately account for the continued indeterminacy of artifacts in use: the meaning of bridges may change over time.

In the case of the social construction of CAPM the relevant social group with the greatest voice has been the American professional engineers, academics and suppliers who have systematically attempted to define and redefine CAPM through APICS. These discourses are then embraced at a local level by other actors in pursuit of their own interests. This state of affairs is well expressed by Corke (1989) when he notes the great hype that surrounds the whole area of computing and production technology

> "Well I think everyone hears of computers being used nowadays, and if they're not being used, and they've got something that's creaking, or your losing competitiveness, or whatever's frightening people, people will say either .....'why can't we have computers, and so they start looking and where they finish....is anybody's guess. The fate worse than death is to invite the IBM salesman...He's selling a solution....they don't go round saying ' well this is my product, but I don't really think you want it.'"
>
> (Interview 1989)

Kling makes the point that there are often discrepancies between the ways in which organisations actually undertake and experience the implementation of computer based systems, and the way in which discourse at both a local and wider level reconstruct the events and outcomes. Kling also argues that the benefits of computer technology are often very difficult to assess but nevertheless command great loyalty in certain quarters. He gives an example of the implementation of an MRP system in which any benefits produced by the system were secondary to the organisational implications for different functional groups. He argues that his case study showed that the MRP system was an instrument for the material managers who found that they could use MRP to gain control over the purchasing staff and to help production line managers in their battle with projections made by marketing.

> "The ideology of MRP impacts helped the material managers to mobilise support for the organisational changes needed to make the system work locally"
>
> (1991a: 353)

This is a striking parallel with the situation at ElectroCo where the computer system was a central plank in the political struggle for control of central resources. Kling suggests that the impacts of MRP were best understood in terms of the organisational changes that followed, especially the tightening of work discipline. But he goes on to suggest that such mobilising ideologies are anchored in wider social discourses that are often derived from the ideas of technological utopianism. Thus the use of specific technologies is located as an 'enabling element' of a broader discursive framework committed to a utopian vision. What is more, the relationship between suppliers and users cannot be understood in classical market terms as important forms of computerisation can be seen as the product of 'loosely organised social groups' (Kling and Iacono, 1988)

> "Groups that form around a computer technology form a social movement to the extent that they (a) have mobilising ideologies that promote an improved social order or oppose an intolerable one, (b) form organisations that include a diverse membership, and (c) promote the movement through communication channels and publications"
>
> (1991a: 354)

Further, ideologies are more likely to be potent in the face of ambiguous evidence to make simple sense of complex and conflicting events and information. Kling identifies the basic shared ideological beliefs as being: that computer based technologies are central for a reformed world; the improvement of computer-based technologies will help reform society; no one loses out from computerisation; more computing is better than less; and there are no conceptual limits to the scope of appropriate computerisation; perverse or undisciplined people are the main barriers to social reform through computing.

What Kling is referring to here is not a description of the actual content of social movements but the discursive backdrop that enables some messages to appear more coherent than others because they fit in with the evolving orthodoxy. He is not suggesting that there is no value in computerisation but rather that accounts of computerised technologies cannot be taken at face value because they are permeated by shaping ideologies that are not self evident

> "...most computer based systems are installed with little public view of the social visions held by their designers, developers, and implementors....the rhetorics justifying these developments are often anchored in images of an ;'information society'. All such single labels to characterise an era are misleading. But the labels are important when they catch on and shape popular discourse and influence policy debates and organisational action."
>
> (1991a: 355)

Ideologies emanate from various sources. Key players involved in organisational innovation are often linked by other networks to sources out side of the organisation where they learn, refine, in turn, themselves promulgate these ideologies. As such, stories of technological effectiveness cannot be treated uncritically as reliable knowledge. An interesting example from the case studies of the ways in which meanings circulate in networks and help to structure the way in which actors build accounts comes from PlastiCo. The Managing Director spent a great deal of time talking about how they were applying Japanese methods of Just-In-Time and that was a key element of his management philosophy. He had completed a doctorate at Aston University and it later emerged that he had used his contacts there to brief himself on 'JIT' after having received a head office circular referring to it. His contact happened to be one of the members of the research group investigating CAPM, and so we have the rather odd situation of a researcher from Aston University interviewing an manager only to receive an idealised account of his activities derived from the researcher's own group! This problem of circularity , as Kling points out, makes it problematic to take accounts of innovation at face value.

Most of Kling's account is directed at the discourses that surround the relationship between social change and computerisation but he also turns his attentions to questions of epistemology and ontology when he raises issues related to studying technological systems. Of particular interest is the way in which he problematises the unit of analysis in the study of computerisation.

> "A good deal of discourse about computerisation focuses on the convenient fiction called 'the computer system'...that deletes the nuances of technical differences and social organisation when these do not matter. But since different technical features of the computer system and the social organisation do sometimes matter, the convenience becomes a liability if our conceptual language is imprisoned in talk about 'the computer'."
>
> (1991a: 356)

He uses the term 'computer based systems' to overcome this limitation and suggests that these have technical characteristics in both design and use, but also have important social characteristics. People's behaviour with computer based technologies can represent ascribed social characteristics as much as technical features, for example the social perception of a perfectly adequate machine being old fashioned. Often specific interactions with computers are defined less in terms of the artefact than in terms of the way it has been embedded in an organisation so that complaints against the system might, more properly be complaints against organisational feature e.g. access or lighting etc.

Because a computer based system, as the earlier case studies demonstrate, is not something that is simply parachuted into a preexisting organisation that remains relatively unchanged the social arrangement that accompany its introduction is an essential element in 'the system'. To focus on 'the computer' as either a source of problems or solutions is to ignore the key fact that the same equipment can have very different consequences in different social contexts, which include the history of social arrangements and infrastructures of support.

Computer based systems, in general, and MRP based systems in particular, then, prove problematic for the SCOT approach, as their indeterminacy and availability to interpretive flexibility is continuous and thus resistant to stabilisation and closure. Such systems continue to be constituted in discourse and discursive practices in use as well as in production. It could be argued that stabilisation occurs at a local level as each organisation that adopts undergoes its own controversy leading to consensus but the evidence that suggests widespread dissatisfaction amongst users would indicate that any such consensus is fragile at best. But even if this is the case the question remains just what is it that is 'stabilising'? Kling's idea of the computer as a convenient fiction is useful in that it directs attention to the social structures and processes that surround computerisation and away from the computer system itself. It is clear that in each of the case studies computerisation was just one element in quite broad ranging restructuring of organisation and routine and yet it is the computer system that takes the credit for benefits derived. But it is by no means clear that the computer system is at all a causal element in this.

The journal 'International Management' ran an interesting report in 1987 that brings this issue into sharp relief. It concerned a court case between the confectionery company Mars Inc. and the OPT group owned by Moshe Eliyahu "Eli" Goldratt the inventor of Optimised Production Technology, another production control technology. According to Goldratt, the system works by increasing productivity by using bottlenecks as a basis for determining realistic schedules, and is based on a secret. al.gorithm that is sealed in a "black box" resembling a highly sophisticated piece of equipment. The Mars company was one of the first users of OPT and they reported a 5% increase in overall output and up to 15% increase in the output of a few of its centres. Other companies reported similar improvements (Aggarwal, 1985). However the litigation stemmed from an allegation made by Mars that the software did not work. Subsequently Goldratt admitted that the sealed black box was a red herring and the software simply a 'numbers cruncher'. In simple terms Mars accused the emperor of having no clothes. The point is that if the software did not work then what was responsible for the improvement in performance reported by Mars and other companies. OPT continues to be shrouded in secrecy, and the fact that Goldratt's company will only agree to implement the computer system if users agree to adopt a whole manufacturing philosophy and organisational change is, in itself, significant. It has been suggested that this alone, without the computer would account for observed improvements in efficiency (Meleton, 1986). PlastiCo would appear to be a case in point, where the organisational changes that accompany the installation of a computer system are what is most important.

It must be stressed that this process, within organisations, cannot adequately be captured by Rogers' concept of routinisation as the consensus may be, as in the case of PlastiCo, to abandon the system altogether in favour of low tech solutions. In Rogers' model this would be seen as discontinuance and failure, when in fact, it may well represent the most appropriate response to the imposition of a discursive framework that was inappropriate in that context. This shift from high tech to low tech leads to another interesting angle in the discursive production of CAPM.

The issue of the interpretive flexibility of MRP based systems is taken to a new level in the context of the controversy over MRP and JIT. We have noted above that Bijker (1993) has identified three different ways in which the dynamics of technological frames can be understood and one of them is in the context of the existence of two competing frames at the same time. We have also seen how technology embodies visions of different groups that may be in conflict (Callon, 1980, 1989).

Webster (1991) has argued convincingly that CAPM systems can be understood in terms of the tension between dominant generalised patterns of work organisation which are embodied in them, and the modifications to these that occur in actual contexts of implementation by users at a local level who reshape the technology to their own requirements. There is evidence from the case studies to support this view. However, in my view, she overestimates the flexibility of 'CAPM' systems to be adapted to very different dominant templates. In particular, she notes how various suppliers of MRP(II) were quick to incorporate claims about JIT capabilities into their sales brochures, but these promises have not easily been fulfilled, if at all. This adds a further dimension to the problems experienced by users: 'CAPM' systems not only embody "visions and programmes of work organisation" (Webster, 1991: 209) - they embody *competing* visions and programmes and this conflict threads its way through to implementation contexts. The task of 'reinventing' is compounded by conflicts in the "silent origins" (Clark and Staunton, 1989: 75). The struggle of organisations to adopt MRP based systems is, in my view, characterised by just such a conflict. This conflict is visible through the long running controversy around two different philosophies of work organisation in the 'push/pull' debate.

Push/Pull controversy and the challenge of JIT

During the 1980's a key feature of the changing economic environment has been the increasing influence of 'Japanese' methods of production. APICS commissioned a number of tours and reports to try to identify the basis for Japanese success and to discover if the Japanese approach was culture specific or transferable. The report of the 1981 tour came to an interesting conclusion concerning Japanese success in the very areas where MRP appeared to be experiencing problems

> "We were forced to the conclusion that those companies that we observed had merely taken common sense and techniques known to all of us, applied them with dedication, and achieved results that we would not have thought possible. We found that the thorough, logical progression of ideas combined with persistent attention to detail were important features of their approach. We saw little that could not be adopted for use in the United Kingdom."
>
> (PA International Report, in Groves 1990: 62)

The striking fact is that Japan had been achieving far greater levels of inventory reduction, quality, production efficiency, and customer service than Western counterparts using 'common sense' and low tech solutions. This triggered a massive interest in Japanese philosophies and techniques and spawned numerous attempts to incorporate them into both the U.S. and the U.K.. The tensions between the two approaches evident in the above quote found its expression in the Production Engineering literature in a controversy over whether Japanese methods were compatible with American ones which took the form a debate around 'push and pull' techniques in production.

The starting point for the controversy is with the operating logics of two different systems of production control. MRP based systems operate with a push logic and JIT systems with a pull logic.

MRPII is a push system, in the sense that a forecast is generated at the outset and a manufacturing plan developed to meet those demands. The plan then drives the manufacture through the issue of work orders. MRPII is essentially a database of parts, components, finished goods, work in progress and requirements. Lead times and relationships between parts are also held. The computer then calculates the best way to meet the master production schedule which is a plan based on forecasts and orders.

The system roughly works in the following way. Requirements are calculated and forecast. These requirements are then 'exploded' in the Bill of Materials file which breaks down a product into its constituent parts. Net requirements are then calculated by deducting available inventory from gross requirements. Finally a schedule is calculated and work orders are issued to the various work centres. The MRP environment is heavily computerised and this means that although data is readily available, it must also be entered systematically and accurately and this, in turn requires stringent work discipline.

JIT, on the other hand, can be characterised a 'pull' system. Compared to an MRP based system it is very simple. The aim of JIT is the production and delivery of the required items at the required time in the required quantity. It can be thought of as a pull or 'demand driven' system because nothing is produced until just before it is needed. Demand for parts and finished goods therefore pulls goods through the system. In a Kanban system cards are used to pass signals upstream to prompt action and release parts.

The push - pull controversy is an interesting one for two reasons: firstly, because it provides another window onto the interpretive flexibility of production systems; and secondly, because it demonstrates how technologies may embody competing discourses. The focus of the controversy is to what extent are the two approaches compatible. If they are not and JIT is shown to be superior the implications for the 'MRP business' are staggering. The controversy is wide ranging and in the process both MRP based systems and JIT are defined and redefined as being variously techniques, systems, and philosophies that are seen to be compatible in some ways and not in others, but the arguments are by no means simple. Terms like JIT and Kanban are often used interchangeably and sometimes the controversy focuses on MRP (Material Requirements Planning) and at other times on MRPII (Manufacturing Resource Planning). Overall there is a great deal of confusion of terms and foci. Further, there is confusion over just what is being pushed and what is being pulled. Pyke and Cohen (1990) identify at least three different understandings of push and pull in the literature. The first defines pull and push in terms of order release processes, whereas the second focuses on the way information is used in the decision process and they refer to the distinction between global (Push) information and local (pull) information. Other writers make a distinction between centralised (push) and decentralised (pull) decision making in the production process.

This confusion has inevitably led to a plethora of proposed solutions to the dilemma. Overall there has been a strong attempt, in the American and British production engineering literature, to weld a consensus that there is nothing incompatible about the two approaches and the focus has been on specifying the ways in which they can be welded into one comprehensive system. The grail seems to be the application of American computing power to Japanese 'common sense'. Some analysts see JIT as an approach to quality improvement that can be used to improve the operation and performance of MRP based systems (Belt, 1987; Wallace, 1990; Bermudez, 1991). Others see the solution to integration in terms of software modifications (Discenza and McFadden, 1988; Krepchin, 1986; Rao, 1989, Ding and Yuen, 1991). Another view focuses on MRPII (Not MRP) and sees the two approaches as complimentary as MRPII is concerned with logic of planning while JIT is concerned with logic of daily production on the shop floor (Krepchin, 1988; Maskell, 1989; Plennert, 1990; Lee, 1993). Surprisingly other analysts have taken an almost opposite view by insisting that JIT is a philosophy and MRP(II) is a system. Although there are a number of different definitions of what that philosophy is, from an all out attack on waste (Karmarker, 1989; Wallace, 1990; Shankle, 1992) to a complete system including product design, plant layout, synchronisation of production, worker involvement and continuous improvement (Forman, 1989; Bowman, 1991).

Some writers contend that the integration of the two approaches requires only minor changes to work practices (Benson, 1989; Louis, 1989), while others argue that such a task would, of necessity entail, major organisational changes (Sillince and Sykes, 1993). Yet others identify the problem as one of manufacturing context with MRP based systems more suited to job work and JIT systems to repetitive production (Goddard, 1982; Im and Schonberger, 1988). Some writers have taken the opportunity to try to establish a niche for OPT (Optimum Production Technology) as a bridge between MRP and JIT (Ludigan, 1986) or an advance on both (Plenert and Best, 1986; Ramsay, M. et. al., 1990), despite a widespread distrust of OPT because of the lack of unbiased information and secrecy with which it is surrounded (Meleton, 1986).

Although the vast majority of the articles appearing in the professional journals see the problem as a technical one that should not be too difficult to solve, others see the problem as a more serious and deep rooted one, and argue that JIT is incompatible with the U.S. manufacturing environment. In particular, because American approaches tend to discourage team work (Shahahbuddin, 1992) and any attempt to integrate JIT into the U.S. context would require enormous changes in philosophy and culture (Kono, 1993). While others seem to suggest that the whole debate is misplaced and the emperor may not have any clothes

> "...there are those skeptics that maintain that the push/pull dichotomy is a *fiction* created by academics or unscrupulous consultants to promote their latest theories or systems."
>
> (Pyke & Cohen, 1990: 24)

The idea that what lies behind the push - pull controversy is, when all is said and done, more than technical matter but one which cuts right to the heart of two very different and possibly incompatible philosophies of manufacture is worth exploring further. Goddard (1982) provides a comparison of what he calls 'typical' Japanese philosophy from 'typical' American philosophy (Figure 6). The point of this ideal type representation of the two different philosophies is to suggest that MRP based systems and JIT systems are more than different techniques for organising and controlling production, they are reflections of philosophical commitments, and if they become detached from these they cease to make sense

Figure 7 : American and Japanese Philosophy

Factors	Japanese Philosophy	American Philosophy
Inventory	A liability. Every effort must be extended to do away with it	An asset. It protects against forecast errors, machine problems, late vendor deliveries. More inventory is "safer".
Lot Sizes	Immediate needs only. A minimum replenishment quantity is desired for both manufactured and purchased parts.	Formulas. We're always revising the optimum lot size with some formula based on the trade-off between the cost of inventories and the cost of set up.
Set ups	Make them insignificant. This requires either extremely rapid changeover to minimise the impact on production, or the availability of extra machines already set up. Fast change over permits small lot sizes to be practical, and allows a wide variety of parts to be made frequently.	Low priority. Maximum output is the usual goal. Rarely does similar thought and effort go into achieving quick changeover.
Queues	Eliminate them. When problems occur, identify the causes and correct them. The correction process is aided when queues are small. If queues are small it surfaces the need to identify and fix the cause.	Necessary investment. Queues permit the succeeding operations to continue in the event of a problem with the feeding operation. Also, by providing a selection of jobs, the factory management has greater opportunity to match up varying operator skills and machine capacities, combine set ups and thus contribute to the efficiency of the operation.
Vendors	Co-workers. they're part of the team. Multiple deliveries for all active items are expected daily. The vendor takes care of the needs of the customer, and the customer treats the vendor as an extension of his factory.	Adversaries. Multiple sources are the rule, and it's typical to play them off against each other.
Quality	Zero defects. If quality is not 100% production is in jeopardy	Tolerate some scrap. We usually track what the actual scrap has been and develop formulas for predicting it.
Equipment maintenance	Constant and effective. Machine breakdowns must be minimal	As required. But not critical because we have queues available.
Lead Times	Keep them short. This simplifies the job of marketing, purchasing, and manufacturing as it reduces the need for expediting.	The longer the better. Most foremen and purchasing agents want more lead time not less.
Workers	Management by consensus. Changes are not made until consensus is reached, whether or not a bit of arm twisting is involved. The vital ingredient is "ownership" is achieved.	Management by edict. new systems are installed in spite of the workers, not thanks to the workers. Then we concentrate on measurements to determine whether or not they're doing it.

From Goddard (1982: 41)

> "Without a clear distinction between these Kanban tools versus the attitude and philosophy of the Kanban users, we could easily import the wrong message from Japan"
>
> (Goddard, 1982: 41-42)

Writing in 1982 Goddard sees the way forward as sticking with MRP, as this is more appropriate to the American context, but do it better

> "Certainly, it's not simply installing a new MRP system that will make us better; its how we use it. But MRP represents the right direction.........Without a formal scheduling system that works, most American companies will not get. al.l the players to play team ball. MRP provides the 'glue' that can bond the team together"
>
> (Goddard, 1982: 48)

Here again we have an example of the commitment to the technical solution. But is it realistic to stick with MRP, which is a reflection of a particular management ideology, while at the same time transforming the ideology that supports it? Groves (1990) thinks not. He argues that MRP systems have failed because they are a block to development of philosophy and culture beyond that expounded by Fredrick Taylor and Henry Ford. For Goddard the commitment to MRP is essential to overcome the cultural limitations of American industrial production. For Groves this is the heart of the problem: MRP systems are systems without people.

He characterises the American approach as one that sees the object of management as a process of directing employees efforts, motivating them, controlling their actions, modifying their behaviour to fit the needs of the organisation. Without this active intervention by management, people would be passive or resistant to organisational needs. They must, therefore be persuaded, rewarded, punished, controlled and their activities directed. Management consists of getting things done through other people. Technology is part of management strategy designed to circumvent the untrustworthy human.

He compares this with a highly idealised view of the Japanese approach which, he argues, values people. In this approach the motivation, the potential for development, the capacity for assuming responsibility, and the readiness to direct behaviour toward organisational goals are all present in people; management does not put them there. It is a responsibility of management to make it possible for people to recognise and develop these human characteristics for themselves. The essential task of management is to arrange organisational conditions and methods of operation so that people can achieve their own goals best by directing their own efforts organisational objectives.

Unlike Goddard, Groves does not believe the solution to the push-pull controversy is take MRP, add Japanese philosophy and stir because computer driven MRP systems are designed to take responsibility away from humans and thus cannot be reconciled with a system of work organisation that is based on devolved responsibility.

He argues that, despite the efforts of APICS, the history of computing in the U.S. has been a history of failed computer systems and continuing production inefficiency

> It is a sound engineering principle that energy contained in a system has to show up somewhere. Production and inventory control has become a technologically based endeavour in its own right as proved by the fact that an average APICS international Conference Proceedings weighs some three pounds....When the total amount of effort contained

> in APICS is considered, why hasn't the energy expended over the last 31 years shown up on the bottom line? Where is it all going? The difference between the shadow and the substance lies in failed systems"
>
> (Groves, 1990: 63)

This tension was clearly evident in the case studies. At all the foundries large and small there was a great fear that the introduction of a computer based system would pass power over to employees who would be in a position to sabotage production and for this reason shop floor entry of data, for example, was not considered viable. The idea of passing responsibility onto shop floor operatives seemed inconceivable

> "One needs to be careful. There are certain people out on the shop floor who would love to get their hands on it, if people thought they could make a mess of the computer"
>
> (BritCo)

In Groves view, the continued commitment to the American management philosophy serves only to ensure that large computer-driven projects are operated so as to guarantee high cost overruns or failure.

> "This is one of the world's best-kept secrets because it is ignored by the suppliers, the users, and, most surprisingly, by the people who have to pay for systems that fail or are never delivered.:
>
> (Groves, 1990: 63)

For him there is no quick technical fix. The problems of MRP based systems failure to provide the same levels of production efficiency as Japanese methods cannot be reduced to a set of variables like, involvement of top management, accurate data input, education etc, because the very existence of an MRP system represents the embodiment of a philosophical approach to work organisation and management which is the real barrier to improvement.

Groves offers a very idealised view of Japanese methods but what is crucial is the degree to which he makes it clear that computer based technologies, like MRP(II), can only be fully understood in terms of the social values that they embody, and the social regimes that they entrench, and that it is insufficient to think of it as a bundle of technical components.

This controversy that surrounds push-pull is not just a matter of academic interest. It impinges directly on the experiences of users attempting to make sense of competing signals from different groups. So, on the one hand, suppliers are peddling computer systems as the solution to contemporary problems in industrial production, at a time when many organisations are being drawn into networks that operate on an quite different logic, and this finds its expression in the difficulty experienced by some actors in the case studies to make sense of it all.

Here again PlastiCo stands out as a case where a low tech solution succeeded where the high tech one failed dismally. At FoundryCo there was anguish over the fact that the components which were pushed through their production system were being returned by customers who had not yet sent the signal to pull them. The production philosophy at FoundryCo quite closely matches the one outlined above as an American approach in which, for example, pushed components through the system and tolerated certain rates of scrap. But this was unacceptable in the new situation. It is in situations like this that the push/pull controversy is lived out and the issue of the interpretive flexibility of the technology is more than of passing academic interest.

CHAPTER 9

Conclusion

The starting point for this research was the processes surrounding the adoption and implementation of CAPM systems in the face of evidence that strongly suggests that the spread of such systems through British manufacturing industry was slow, patchy and implementation characterised by a high degree of failure. The Rogers model was applied to a number of case studies in order to try to identify and explore issues that have contributed to this situation. The end point is that rational models of adoption and implementation are too limited to capture the rich complexity of the ways in which computer based systems are socially constructed in a struggle for meaning characterised by the interaction between a whole set of discourses at a variety of different levels.

Rogers model is, in many ways, concerned with methodology, identifying just what it is that individuals and organisations who 'successfully' negotiate this process do, so that this may be codified and diffused to the less successful. CAPM systems were seen by government and professional engineers as an essential ingredient of economic regeneration and have been sold to users by suppliers as the solution to all their problems. Users are often highly amenable to such pressures as the belief in the transformative capacity of technology for the better is deep seated in Western culture, and operates at every level from founding discourses of technological advancement and progress, apparent in classical accounts of technology, to the paradigmatic commitment of professional groups of engineers to the solution to most problems as more technology, and to the commitment of managers at a day to day level to the quick technical fix.

The literature on adoption and implementation, like Rogers' model, for the most part tends to focus on what adoptors and implementors are doing wrong and as we have seen, common lists range from inaccurate data records to lack of top management involvement, lack of education etc. What such accounts have in common with Rogers is the degree to which the adoptor is pathologised and thus the focus for remedial treatment.

There is no doubt that there is more than a grain of truth in this fixation, some users of these computer based systems are more experienced, more knowledgeable and better able to enact adoption and implementation strategies. But this is only part of the story. The most 'successful' case in this research was clearly the ElectroCo company; does this mean that had the other companies done what they did then the outcomes would have been very different - is it just a case of transferring one set of practices from one context to another? This is the kind of solution propounded by Rogers, and by a great deal of the literature from production engineering. They are tinged by assumptions that such processes are inherently rational, and universal exemplars of best practice can be identified and imitated. But the 'reality' is much more complex.

The issues of success and failure are highly problematic in the first place. The history of MRP based systems has been a history of failure (Groves, 1990) despite the fact that over a period of nearly a quarter of a century an enormous amount of energy, and paper and ink, have been devoted to generating the great exemplars.

The root of the problem, in my view, is that the processes surrounding the adoption and implementation of such computer based systems have been poorly understood as rational and linear, and the technology itself has been viewed in crude objectivist terms. Thus, if the technology is a neutral object and the adoption and implementation is a matter of rational organisation then the only way left open to explain failure is in pathological terms.

The exploration of these processes and of the nature of the technology have, I hope, helped to go some way to understanding the situation in richer terms. I have tried to show how rational accounts are flawed on a number of grounds. Rogers model begins with the identification of a performance gap and this spurs the search for solutions which are identified in a largely neutral and passive environment and then brought within the boundaries of the organisation and incorporated into the ongoing routines. But this view greatly underestimates the degree to which the environment is an active structuring context in which actors are located. Thus the search for solutions does not, necessarily begin with the organisation and gradually move beyond the boundaries in a process of rational searching. This whole process is not only bounded by the internal routines of the organisations but also those routines are subject to the structuring influences of the environment which shape the knowledges, practices and expectations of actors within organisations. In such a situation the solution tends to preexist the problem. CAPM is, in my view, a solution in search of a problem on a grand scale. The process of adoption is better understood, not as a variant of rational choice theory, but more akin to the invasion of organisations by discourses of modernity masquerading as objective technical artifacts and technological solutions, and the 'subversive' practices of actors in local contexts.

Given this, accounts of success and failure of the kind outlined in chapter four, based upon technical and functional specification, are missing the point. It was noted above that ElectroCo appeared to be a text book model of successful implementation and it would be easy to deduce from this that it is simply a matter of methodology but there is more to it than this. Despite the history of failure associated with MRP based systems the greatest degree of 'success' has been experienced in 'T-Type' industries (Webster, 1991), that is those with similar characteristics and contexts to the motor industry and electronics assembly places, like ElectroCo. This is a highly significant observation because it raises the question of transferability of methodology and throws into doubt the idea of success based on exemplar and imitation.

This idea is based on an assumption of universal applicability: it may be recalled that Corke, in his book, argued that there are only two reasons why CAPM implementations fail - either the wrong equipment is being used or the principles of production engineering are not being followed. Thus solutions are universal and universally applicable. However, his later shift to an understanding of CAPM as "gardening" and something that people do is, in my view highly significant as it hints at both the continuing indeterminateness and the interpretive flexibility of CAPM in use, which makes the former view highly problematic. CAPM is available to a great deal of interpretive flexibility in use and this, in turn, raises problems with the concepts of 'stabilisation' and 'closure' as they are limited in the ways in which they enable us to understand CAPM. In Bijker's view stabilisation occurs at a universal level - a bicycle is a bicycle in any context and any problem in riding one may, quite properly, be understood in terms of the individual pathologies of different riders. However, we have seen that Bijker underestimates the degree to which interpretive flexibility may continue in use, following the design and production stages. Kling has argued, convincingly in my view, that computer based systems continue to be subject to interpretive flexibility in use, and that what a computer based system actually is, is a moving feast and is dependent upon the discourses that surround it for its 'stability' or meaning. Bijker has attempted to address this issue by shifting the focus from artifacts to ensembles but even this underestimates the continued interpretive flexibility of artifacts in use. For example, he argues that once an artifact has stabilised and closure occurred that the process of closure is irreversible, but this is difficult to sustain even at the level of artifacts. In contrast Woolgar (1991), for example, has taken issue with Winner's idea of bridges as concretised inequality as the meaning the bridge may have at the point of design and production gradually gives way to new meanings over time as contexts change. Artifacts, are always subject to the possibility of destabilisation and restabilisation. For example, in the world of electric amplifiers the valve base amp was superseded by the solid state amp during the late 1960's and early 1970's, but whereas Bijker would see the destabilisation of the bicycle and its restabilisation in the form of the penny farthing at a later date as impossible, that is exactly what is happening in the world of electric amplifiers where the 'old fashioned' valve amplifier is making a come back, is considered a superior technology to solid state, and now features at the top end of virtually every manufacturers catalogue (see for example the Marshall Catalogue 1995).

The implications of this for understanding computer based systems are important. The notion of stabilisation continued in SCOT is a generic, universal one that provides a degree of solidity of artifacts in use. But in the case of computer based systems stabilisation cannot be understood in this way. I have argued above that 'CAPM' is a technology that is 'always becoming' and what this means is that consensus over its nature can never stabilise at a universal level - as soon as one consensus appears close at hand it is wiped away as new meanings and possibilities present themselves. Thus stabilisation can only ever occur at a local level as the meaning of the 'computer based system' is clarified in particular contexts. Even then, as BritCo discovered, stabilisation is only likely to be partial and temporary. The implications for the exemplar, imitation model are clear; it simply does not make sense to try to transfer a system from one context to another as the meaning is derived from that context and not from some universal characteristics of the technology or exemplar of adoption and implementation.

This all has important implications for the way in which technology and the innovation process is understood. CAPM must be understood in terms of a complex relationship between technical artifacts, universal discourses of modernity which are translated into competing, paradigms of industrial organisation, and local contexts. There are a number of accounts of this but, in my view, there is a need to extend them to include an account of the continued indeterminateness and interpretive flexibility of computer based systems in use. It is clear that both the *form* and the *content* of innovations are not fixed entities, but there is also a need to extend this notion to include the *purpose* of the innovation.

Clark and Staunton (1989) used the concepts of 'contingent specificity' and 'dynamic configuration', in an attempt to capture this complexity. Contingent specificity, attempts to avoid pro-innovation bias and draws attention to the problems of 'fit' between innovations and users. Dynamic configuration is deployed to show that innovations are 'bundles of elements' and various forms of disembodied knowledges that have to be unbundled and rebundled by users in specific contexts. Webster (1990, 1993) is concerned with the ways in which technologies are shaped by the interaction between discourses of work organisation and local contexts and she has shown that implementation requires a good deal of customisation of computer systems so that they can be matched to users needs.

> "The implementation process therefore involves attempts to reconcile general discourses of work organisation with local practices, and during this, technologies are modified, assuming some features of the manufacturing systems employed by user companies"
>
> (54)

In the face of technologies embodying competing paradigms there is a need for 'blending' on the part of users (Clark and Staunton, 1989) and Clark and Newell (1993) have extended this idea to explain the patchy success rate reported in Britain (Burcher, 1991, in Clark and Newell, 1993). They show how in the British context the outcome of such attempts has been problematic in the absence of key knowledges

> "...the appropriation of these control systems appears to happening, for much of the time, in a haphazard and muddling way. We interpret this as being due to the absence of key templates and corporate translations for this innovation in the British context."
>
> (79)

I concur with these conclusions up to a point but, in my view, they operate within a Rogerian, and therefore restricted, understanding of reinvention.

Rogers' notion of reinvention emerges as a concept of considerable, if camouflaged, potential. Rogers is unclear about the extent or degree of reinvention but he recognises that this possibility constitutes actors as active participants in the innovation *and* invention process which can no longer be separated, although he does not discuss the implications of this for his own model of diffusion! He sees reinvention as a continuation of the rational process of implementation as reinvention concerns tailoring the innovation to the particular needs of the users: in terms of CAPM this would amount to the adoption of a particular sub set of modules which might be rewritten to a greater or lesser extent , but still used the innovation for the purpose for which it was designed but he resists the extension of the concept to include interpretive flexibility

> "re-invention is a more apt term than others...like the anthropological concept of *reinterpretation*, the process in which adopters of an innovation use it in a different way and /or for different purposes than when it was invented or diffused to them."
>
> (Rogers 1983: 176 [footnote])

Kling (1991) has shown, and the case studies demonstrated, this is exactly one of the outcomes of the interpretive flexibility of computer based systems: they can be used in all sorts of ways unimaginable by their 'inventors' or suppliers: as tools in internal political struggles; as status symbols for the outside world; as citeable achievements in strategies of career advancement; and so on.

Notions of configuration refer to the form and content of technologies, which are complex and malleable and shaping occurs in use and over time. However, the purpose of the innovation is taken for granted. By this I mean that the reinvention of computer based technologies is analysed in terms of the use *for which it was designed*, and the focus is how that purpose is translated through the social shaping of the technology in different contexts. Thus the 'failures' of implementation are explained in terms of the mismatch between the context and the dream. This may be the case, in many instances, but it is not the whole story as it underestimates the indeterminateness of the technology and continuing potential for interpretive flexibility.

Clark and Newell (1993) convincingly explain the problems with implementation in Britain in terms of problems of the translation in the absence of key templates, but how are we to explain similar failure in the U.S. where such templates do exist? I have argued that the history of MRP based systems is a history of failure; it is also a history of subversion of purpose. We can only categorise one case as successful and another as failure if we apply the yardstick of the purpose for which the technologies were designed: for example in the case of CAPM, the control of manufacture. In some instances this would be appropriate as the users may share the same purpose as designers but this is not always the case, and if we apply other yardsticks, purposes, then we will see the situation in a new light. For example, in the case of BritCo if we apply the yardstick of production engineering visions then the implementation was a failure as the system is not extensive or well integrated and in particular it is not used and manual systems continue to operate side by side with it. This is akin to saying a gun that does not fire is not a gun as it does not fulfil the purpose for which it was designed. However a gun may have many other meanings, trophies status symbols and so on.

Re-invention is essential in a situation where the nature of the innovation is structured by diverse and competing meanings which actors must decode and reconstruct in their own way. Thus it is not simply technical aspects of an innovation that are reinvented but the very meaning of it. Further, the process of reinvention occurs in a setting structured by discourse and to understand the success and failure of computer based systems it is necessary to understand the ways in which actors generate their own meanings in this context.

This does not mean that 'anything goes' and CAPM can be anything to anybody. Woolgar (1991) and Grint and Woolgar (1992) take an extreme position here when they assert the "constitutive function of interpretation" (1991: 374). They resist the placing of limits on the process of interpretive flexibility, and they take issue with the view that technical artifacts can be inscribed with meaning or purpose independently of the specific contexts in which they are constituted. Woolgar (1991) engages with Winner (1986) and argues that bridges could be flexibly interpreted in a variety of ways: technology can be seen as a text that can be read in many different ways. He claims that

> "..the reflexive version of technology as text suggests that all versions (descriptions, accounts) of technology be granted no greater authority than any other outcome of textual production and interpretation."
>
> (1991: 41)

He dismisses Winner's account as a "preferred reading" that carries no more weight than any other. The problem with Woolgar's position is that all accounts are equally privileged, but it is difficult to see how this can account for the fact that some readings are clearly more 'preferred' than others. The essential task is to provide an account of the apparent stability of meaning in the face of an infinite range of possible readings.

Bijker's account of technological frames is useful here and CAPM can be partially understood in terms of Bijker's model of two competing frames coupled with the negotiated outcomes in local contexts. However the weakness of Bijker's position is that the very idea of *technological* frame concentrates attention on processes of design and production, and underestimates the importance of processes during consumption and use. In my view Woolgar is correct to identify the active role of the user in producing other possible readings, but he is mistaken in assigning boundless limits and in rendering all readings as equivalent. It is useful here to distinguish between his use of the term "preferred reading" to that of Stuart Hall (1980). For Woolgar the term is used to undermine any special status accruing to the analyst's reading which, interestingly, also,

> "includes our own texts, in which we as analysts conventionally privilege our own status vis-a-vis the relativised status of the texts of others."
>
> (1991: 41)

For Hall, however, preferred readings

> "...both have the institutional/political/ideological order imprinted in them and have themselves become institutionalised. The domains of 'preferred readings' have the whole social order embedded in them as a set of meanings, practices and beliefs."
>
> (1980: 134)

Thus textual appropriation is mediated by pre-existing encoded meanings which offer themselves as natural and given and construct some of the limits within which decoding will operate. At the same time Hall refers to a 'residual pluralism' that means that other private, individual, variant readings may be possible but, for him, they will always be limited. In my view Hall's interpretation is more persuasive as it allows for flexibility without abandoning analysis to the extreme polysemy of Woolgar. At the same time, in the context of 'open' computer based systems, we should not underestimate the role of 'residual pluralism'.

Thus, making sense of CAPM and reinventing it means making sense of the competing and conflicting discourses which are embodied in the process of its diffusion and implementation. In this sense, success or failure cannot be measured in terms of the degree to which the CAPM system has been implemented, integrated and is used. This may be a successful outcome in one context but not in another. Kling's concept of a "computer *based* system" is helpful here because it implies that the 'computer system' can never be disembodied from the social context of which it is a part. The adoption and implementation of CAPM is centrally a struggle for meaning. This struggle is undoubtedly conducted in the context of Hall's 'preferred reading'. or what I have referred to as 'inscribed purpose'. But this struggle may take diverse forms and be shaped by other different purposes that go well beyond technical and functional aspects. To ask 'is an implementation successful'? is to a make an assumption about universal purpose that may not be appropriate to *understanding* the specific contexts in which meaning is constituted.

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